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BULLETIN

OF THE

TORREY BOTANICAL CLUB

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Vol. 47 No. 9

BULLETIN

OF THE

TORREY BOTANICAL CLUB

SEPTEMBER, 1920

Calymperaceae of North America

R. S. WILLIAMS

(WITH PLATES 15–17)

The next part of the North American Flora relating to mosses will comprise the families Fissidentaceae and Calymperaceae. The second of these families includes only two genera, *Syrrhopodon* and *Calymperes*. The results obtained from the study of this group are here offered in advance, partly to allow the illustrations of cross-sections of the leaves to be issued with the descriptions.

SYRRHOPODON Schwaegr. Suppl. 2^2: 110. 1824

Dioicous or rarely autoicous. Growing in mostly compact cushions of pale green to greenish brown color with more or less radiculose, branching stems from a few millimeters to 6–8 cm. high. Leaves with mostly imbricate, often conspicuously white base, mostly narrowed upward to a point varying from straight to crispate and from lanceolate to lingulate or ligulate, with acute or rounded, mostly denticulate apex and having a distinct border (except in *S. martinicensis*) either much thickened or of hyaline or yellowish cells. Costa stout, from nearly percurrent to excurrent, often papillose or spiny on one or both sides, in cross-section showing one row of guide-cells with rarely a few accessory guide-cells, stereid bands above and below them and outer cells mostly differentiated. Leaf-cells throughout upper part of leaf chlorophyllose and roundish or oval to quadratic, rarely smooth, mostly papillose or mamillose on one or both sides; cells of the erect base mostly hyaline (the cancellinae), square to linear, changing abruptly into the green cells of upper part of leaf. Perichaetial leaves usually smaller than the stem-leaves. Seta erect, elongate

[The BULLETIN for August (47: 325–366. *pl. 14*) was issued October 5, 1920.]

and smooth. Capsule erect, regular, oval to cylindric, mostly smooth and glossy. Annulus none. Peristome-teeth rarely wanting, mostly narrowly lanceolate and undivided, sometimes very short and irregular, usually papillose and golden brown. Lid conical and often long-rostrate. Calyptra cucullate, the base entire or somewhat split, the apex often rough. Spores usually rough. Gemmae often borne on the leaves, either growing from the upper costa or rarely from cells of leaf-blade on either side of the costa. [PLATES 15, 16.]

Type species: *Calymperes Gardneri* Hook.

Leaf-margin with external cells not differing in color or length from those of blade within but sometimes with an inner stereid band.
- Margin much thickened, forming a distinct border.
  - Border triangular in cross-section and more or less doubly serrate-winged.
    - Leaf-base golden brown or reddish.
      - Leaves less than 0.4 mm. wide and about 1 mm. long, the margin sharply dentate with often spreading somewhat ciliate teeth. 1. *S. rigidus.*
      - Leaves mostly over 0.8 mm. wide and about 1.5 mm. long, the margins slightly serrulate above. 2. *S. Bernoullii.*
    - Leaf-base mostly pale or hyaline.
      - Costa very rough with papillae up to 8 mm. high, more prominent on the back in the lower than the upper half of costa. 3. *S. floridanus.*
      - Costa nearly smooth or much smoother on the back in the lower half than in the upper half, with papillae up to 4 mm. high. 4. *S. incompletus.*
  - Border oval in cross-section, not winged and distantly serrulate; cells throughout upper leaf, distinct, mostly oval. 5. *S. Berterianus.*
- Margin not thickened, without a border. 6. *S. martinicensis.*

Leaf-margin with hyaline or yellowish border of narrow, elongate cells (sometimes wanting in upper part of leaf), sharply defined from cells of blade within.
- Border of a mostly cylindric band of stereid cells extending from or near apex to the basal part.
  - Margin entire or nearly so all around except at apex of leaf.
    - Leaves with point crispate when dry and only one or two times longer than the broadened leaf-base.
      - Costa smooth on both sides except at the denticulate apex; leaf-cells densely covered with low papillae. 7. *S. Gaudichaudii.*
      - Costa more or less spiny dentate on back to

below the middle; leaf-cells with often high, spine-like papillae. 8. *S. inflexus.*

Leaves with point spreading-flexuous to incurved or nearly straight when dry and from two to many times longer than the basal part, or without a distinctly broader basal part.

Costa without accessory guide-cells; stems usually much longer than the longest leaves (about 12 mm.)

Leaves rather distant with the point abruptly spreading from the conspicuous, appressed base; costa dentate at apex, not papillose below. 9. *S. Husnoti.*

Leaves closer together on the stem with less spreading points; costa mostly papillose on the back in the upper part as well as dentate at apex. 10. *S. flavescens.*

Costa with accessory guide-cells; stems much shorter than the longest leaves (stems usually 5–6 mm. long and leaves up to 4 cm. long). 11. *S. tennifolius.*

Margin serrulate to enlarged base, or base with more or less serrate or spiny-dentate border.

Cells of leaf smooth. 12. *S. lycopodioides.*

Cells of leaf either mamillose or papillose, that is, similar on both sides.

Costa about 25 μ wide halfway up, smooth except near the apex. 13. *S. recurvulus.*

Costa 50 μ wide or more half way up.

Smooth or with minute, distant teeth on the back, the upper face papillose mostly from just above the cancellinae half way to apex. 14. *S. graminicola.*

Rough with prominent, often spine-like teeth on the back.

Costa spiny-dentate on the back in the upper half, otherwise smooth. 15. *S. elongatus.*

Costa with dense, compound or forking papillae extending to below the cancelinae on the back. 16. *S. texanus.*

Border mostly wanting in upper third of leaf or in some leaves scarcely present or entirely wanting throughout.

Cancellinae mostly broad and somewhat rounded above. 17. *S. ligulatus.*

Cancellinae terminating above in narrowly acute angles next the costa.

Costa near the apex of cancellinae 60–80 μ wide and leaf-blade 0.6–1 mm. or more wide. 18. *S. parasiticus.*

Costa near apex of cancellinae 40–50 μ wide and leaf-blade 0.25–0.50 mm. wide. 19. *S. filigerus.*

1. SYRRHOPODON RIGIDUS Hook. & Grev. in Brewster, Edinb. Jour. Sci, 3: 226. 1826

Calymperes androgynum Mont. Ann. Sci. Nat. II. 3: 195. 1835.
Syrrhopodon longisetaceus C. Müll. Syn. 1: 535. 1849.

Dioicous, male plants much like the fertile in habit, bearing several buds in the axils of the upper leaves rather over 1 mm. long, composed of two or three broadly ovate, lanceolate-pointed, serrulate and costate perigonial leaves, enclosing eight to ten antheridia about 0.5 mm. long, with few paraphyses: in rather compact, dull, brownish green cushions, red-tomentose within, with stems 1–3 cm. high; stem-leaves 7–8 mm. or sometimes up to 12 mm. long, spreading flexuous, from an ovate base 1–1.5 mm. long, with margins sharply serrulate or somewhat spiny-dentate with often spreading teeth, rather gradually narrowed to a linear-lanceolate, acute point up to seven or eight times longer, with thickened, doubly serrate borders; costa stout, excurrent, grooved, enlarged at apex and bearing numerous slender propagula with two or three cross-walls, smooth in lower part, mostly rough above on both sides or rarely nearly smooth, in cross-section showing about seven guide cells, large stereid bands above and below and outer cells differentiated all round; cells throughout upper part of leaf distinct, mostly oblong, 6–8 μ wide and 12–16 μ long, mamillose on upper side, smooth beneath; cancellinae not filling entire basal part of leaf, more or less golden or reddish brown, mostly terminating above in acute angles; perichaetial leaves about like upper stem-leaves, but the inner smaller; seta 2–2.5 cm. long; capsule oblong, about 1.7 mm. long with conical, rostrate lid of about equal length; peristome a low, yellowish membrane, when moist scarcely extending above rim of capsule; spores rough, up to about 22 μ in diameter; calyptra nearly smooth throughout. [FIG. 1.]

TYPE LOCALITY: Trinidad.

DISTRIBUTION: Porto Rico, Guadeloupe, Martinique, St. Vincent, Grenada, Trinidad and northern South America.

ILLUSTRATION: Ann. Sci. Nat. II. 3: *pl. 3, f. 2.*

2. SYRRHOPODON BERNOULLII C. Müll. Bull. Herb. Boiss. 5: 189. 1897

Syrrhopodon Pittieri Ren. & Card. Bull. Soc. Bot. Belg. 41[1]: 54. 1905.

Dioicous, male plants stout, branching, with often abundant axillary flowers, the perigonial leaves mostly golden brown, the

inner ovate, acute, not quite entire, the outer longer with pale, lanceolate, serrulate point, enclosing five or six antheridia a little over one half mm. long with somewhat longer paraphyses: in large, not very compact, greenish brown tufts, with more or less curved, branching stems, tomentose below, up to 4 or 5 cm. high; stem-leaves spreading-flexuous, up to 6 or 7 mm. long, from an oblong-ovate, mostly golden brown base about 1.5 mm. long, slightly crenulate or serrulate on borders, gradually narrowed to a linear-lanceolate point, tubulose when dry, with thick, doubly serrate margins and acute apex; costa not quite percurrent, serrulate on back toward apex, smooth below, one half up about one sixth the width of leaf, in cross-section showing six or seven guide cells, large stereid bands above and below and outer cells differentiated; leaf-margin in cross-section triangular, showing a stereid band surrounded by rather large outer cells; cells throughout upper leaf mostly slightly elongate, the median about 6 μ wide by 7–8 μ long; cancellinae filling a rather small part of leaf-base, mostly broad and rounded or truncate above; inner perichaetial leaves scarcely smaller than outer; seta 10–18 mm. long; capsule ovate-oblong, small-mouthed, about 2 mm. long with a slender-beaked lid 1.5 mm. long; peristome teeth projecting above the mouth about 75 μ, often united to near apex, rather pale, with often numerous, golden brown, wart-like projections over the outer surface; spores rough, 18–24 μ in diameter; calyptra rough near apex. [FIG. 2.]

TYPE LOCALITY: Guatemala.

DISTRIBUTION: Guatemala to Panama and in Guadeloupe (*Père Duss 631*).

3. SYRRHOPODON FLORIDANUS Sull. in Gray, Man. ed. 2, 631. 1856

Dioicous: in compact cushions, greenish brown above, rusty brown within, with more or less fasciculate branching stems, somewhat tomentose below, up to 3 cm. high; stem-leaves incurved or crispate when dry, the upper 4.5–5 mm. long, from an ovate base about 1 mm. long, somewhat narrowed to a nearly linear point three and one half to four times longer with incurved, doubly serrulate-lamellate borders and broadly acute or obtuse, serrulate apex; costa not quite percurrent, about 80 μ wide half way up the leaf, mostly densely covered on the back, from the middle to the broadened base of leaf, with high, almost spine-like, papillae; leaves in cross-section near middle showing a terete costa with five or six guide-cells, large stereid bands above and below and outer cells differentiated; leaf-blade with cells highly mamillose on upper side, nearly smooth or somewhat mamillose

on under side with a leaf-border triangular in cross-section, of about eight cells sometimes enclosing one or two stereid cells; cells of upper blade distinct, mostly somewhat angular, scarcely elongate, 5–7 μ in diameter; cancellinae extending up about 1 mm. from base, mostly rounded, sometimes acutely angular at apex; perichaetial leaves scarcely differing from those of upper stem; pedicel erect, 7–8 mm. long; capsule ovate-cylindric, about 1.75 mm. long, the flattish lid with acicular beak rather shorter; peristome-teeth attached well below the mouth, somewhat irregular, short-lanceolate, pale, projecting above the rim 50–60 μ, with five or six articulations; spores rough, about 16 μ in diameter; calyptra slightly rough above. [FIG. 3.]

TYPE LOCALITY: Florida.

DISTRIBUTION: Florida, Alabama, Georgia and Bermuda.

ILLUSTRATION: Sull. Icon. Musc. *pl. 31.*

This is very close to the next species, but the costa is usually much rougher on the back, and the cells of the upper part of the leaf are less inclined to be slightly elongate.

4. SYRRHOPODON INCOMPLETUS Schwaegr. Suppl. 2^1: 119. 1824

Syrrhopodon Hobsoni Hook. & Grev. in Brewster, Edin. Jour. **3**: 224. 1824.

Syrrhopodon semicompletus Schwaegr. Suppl. 2^2: 97. 1827.

Calymperes Hobsoni Grev. Ann. Lyc. N. Y. **1**: 271. 1825.

Syrrhopodon Mohrii C. Müll. Linnaea **38**: 633. 1874.

Syrrhopodon brachystelioides C. Müll. Nuovo Giorn. Bot. Ital. II. **4**: 48. 1897.

Syrrhopodon decolorans C. Müll. Bull. Herb. Boiss. **5**: 188. 1897.

Dioicous, male flowers one to several, terminal and axillary, the inner perigonial leaves short, broadly ovate, acutish, costate, minutely serrulate, nearly or quite without green point, enclosing numerous antheridia and paraphyses a little over 0.5 mm. long: in extensive, brownish green mats with more or less curved and branching stems 1–5 cm. long; stem-leaves 4–5 mm. long, from a rather broad, ovate or obovate base serrulate on margins above, abruptly narrowed to a broadly linear, when dry often subtubulose, point with thickened doubly serrulate border extending to the broadly acute or somewhat rounded serrulate apex; costa not quite percurrent, 60–70 μ wide one half up leaf and about one sixth leaf-width, at apex denticulate, below from nearly smooth on both sides to more or less papillose (the papillae mostly 1–4 high) on back down to cancellinae, in cross-section showing about

six guide cells with stereid bands above and below and outer cells differentiated; cells throughout upper part of leaf from nearly square to hexagonal, often slightly elongate, the median mostly 5–6 μ wide and 6–8 μ long, mamillose on upper side, smooth or slightly mamillose or papillose on under side; cancellinae filling two thirds to three fourths of the leaf-base, broad and rounded above; inner perichaetial leaves very similar to outer but smaller; seta 6–7 mm. long; capsule oblong-ovate, small-mouthed, rather over 2 mm. long without lid, the beaked lid about two thirds as long; peristome a rather pale, smoothish membrane not extending above the mouth, often nearly entire; spores rough, 16–18 μ in diameter; calyptra slightly rough above. [FIG. 4.]

TYPE LOCALITY: Cuba.

DISTRIBUTION: Mexico, Florida, Cuba, Jamaica, Porto Rico, Montserrat and Guiana, South America.

ILLUSTRATION: Schwaegr. Suppl. 2: *pl. 180.*

EXSICCATI: Krypt. Exsic. Mus. Palat. Vindob. *1896,* as *Syrrhopodon Hobsoni.*

5. SYRRHOPODON BERTERIANUS (Brid.) C. Müll. Syn. 1: 539. 1849

Dicranum Berterianum Brid. Bryol. Univ. 1: 445. 1826.

Syrrhopodon laevidorsus Besch. Rev. Bryol. 18: 75. 1891.

Apparently dioicous, male flowers not found: in rather loose, deep, brownish green tufts with stout stems up to 7–8 cm. high; stem-leaves 5–6 mm. long, from a broad, obovate, erect and clasping base, slightly serrulate on margins above, abruptly narrowed to a linear, spreading-flexuous point with acute apex and thickened, distantly serrulate borders; costa not quite percurrent, nearly one third the width of upper leaf, terete, smooth on both sides; leaf in cross-section showing about six guide-cells in costa with large stereid bands above and below and outer cells differentiated all round, the leaf-border of a small stereid band enclosed by larger outer cells; cells throughout upper part of leaf distinct, mostly oval, 6–8 μ wide by 8–12 μ long, smooth on under surface, mostly mamillose above; cancellinae filling one half to two thirds of leaf-base, broad and rounded or truncate above; perichaetial leaves very similar to stem-leaves; seta 10–13 mm. long; capsule oblong, up to 2.5 mm. long with conical, slender-beaked lid two thirds as long; peristome not seen; calyptra smooth; spores rough, spores rough, up to 16 μ in diameter. [FIG. 5.]

TYPE LOCALITY: Porto Rico.

DISTRIBUTION: From Cuba and Jamaica to Trinidad and northern South America.

6. SYRRHOPODON MARTINICENSIS Broth. Symb. Ant. 3: 422. 1903

Flowers and fruit unknown: in dull green cushions with stiff, erect stems 2–2.5 cm. high, in cross-section showing two to four rows of outer, thick-walled, golden brown cells and no central strand; stem-leaves 3.5–4 mm. long and 1 mm. wide, when dry obliquely incurved or appressed-imbricate, forming a compact bud at apex of stem showing the conspicuous, glossy, whitish costae, the leaf either oblong-ovate or slightly obovate, the base more or less yellowish; leaf-margin incurved when dry, not thickened, papillose on border, otherwise entire or slightly denticulate at apex; costa percurrent, broad and yellowish at base, about 300 μ wide and one third the width of leaf, tapering gradually to apex, in cross-section near middle showing about seven guide-cells with stereid bands above and below of about equal size and outer cells scarcely or not differentiated; cells throughout upper part of leaf more or less hexagonal, scarcely elongate, on upper side mostly mamillate and unipapillate, on under side papillate; cancellinae of leaves growing from below the apex of stem distinct, broad, extending about one third up leaf and terminating in rather acute angles; cancellinae of inner leaves at apex of stem rather ill-defined and leaf-cells on either side of costa just above the cancellinae mostly covered with a dense, green mass of filiform propagula up to 0.8 mm. long, with twenty-five cross-walls. [FIG. 6.]

TYPE LOCALITY: Martinique.

DISTRIBUTION: Guadeloupe and Martinique.

7. SYRRHOPODON GAUDICHAUDII Mont. Ann. Sci. Nat. II. 2: 366. 1845

Dioicous, male plants about like the fertile, with often several antheridial buds aggregate near the apex of stem, the antheridia few, without paraphyses, enclosed by several short, ovate, serrulate, costate, brownish leaves: in compact, green tufts, showing the conspicuously white leaf-bases, with branching stems 1–3 cm. high; stem-leaves more or less twisted and crispate when dry, from an obovate or oblanceolate, nearly or quite entire, erect base narrowed to a linear-lanceolate or nearly linear, deeply grooved point from mostly as long to about twice longer than basal part, with a hyaline or yellowish border, entire except at the broadly acute, denticulate apex; costa not quite percurrent, smooth

on both sides except at the denticulate apex, about one sixth the width of leaf at middle, in cross-section showing mostly four guide-cells, a stereid band much larger below than above and outer cells not differentiated; cells of upper part of leaf rather obscure, about 6 μ in diameter, densely papillose on both sides; cancellinae filling most of basal part of leaf, somewhat rounded or truncate above; outer perichaetial leaves much like the stem-leaves, the two or three inner much smaller, of mostly hyaline cells, often slightly serrulate; seta up to 5 or 6 mm. long, not quite smooth above; capsule erect, oblong, scarcely 1.5 mm. long, with convex-conical, rostrate lid about 1 mm. long; peristome-teeth golden-brown, not quite smooth, lanceolate, entire, projecting about 80 μ above the rim of capsule with rather prominent articulations; spores rough, 12–14 μ in diameter; calyptra not seen. [FIG. 7.]

TYPE LOCALITY: Isle of St. Catharine, Brazil.

DISTRIBUTION: West Indies and northern South America.

ILLUSTRATION: Ann. Sci. Nat. II. **2**: *pl. 16, f. 3*.

8. SYRRHOPODON INFLEXUS Mitt. Jour. Linn. Soc. **12**: 117. 1869

Syrrhopodon Sartorii C. Müll. Linnaea **37**: 633. 1874.

Male flowers unknown: in compact, green tufts with somewhat branching stems up to 2 cm. high; stem-leaves with conspicuous, white, imbricate base, twisted and crispate in upper part when dry, up to about 3 mm. long, from an oblanceolate base with entire margin, usually one half to two fifths the length of leaf, gradually narrowed to a nearly linear, grooved point with distinct, entire, pale yellowish border not quite reaching the rather broad, toothed and apiculate apex which sometimes bears numerous spindle-formed or club-shaped propagula up to 100 μ long, with six to eight cross-walls; costa usually smooth except on the more or less spiny-dentate back toward the apex, in cross section showing about five guide cells, stereid bands above and below, the upper band much smaller than the lower and the outer cells not differentiated; cells throughout upper part of leaf mostly rather obscure, highly mamillose or papillose or sometimes almost spiny on both sides, the median about 8 μ in diameter; cancellinae filling most of erect base of leaf, usually rounded above; inner perichaetial leaves much shorter than outer, about 1.5 mm. long, with very short, green, serrulate points; pedicel 4–5 mm. long, bearing an oblong capsule 1–1.5 mm. long with slender-beaked lid about one half as long; peristome-teeth golden-brown, lanceolate, nearly smooth, with rather distinct articulations, projecting above the mouth about 100 μ; spores rough, 14–15 μ in diameter; calyptra rough in upper third. [FIG. 8.]

TYPE LOCALITY: Colombia near Bogota at 6000 ft. alt.

DISTRIBUTION: known only from Mexico and Colombia.

9. SYRRHOPODON HUSNOTI Besch. Ann. Sci. Nat. VI. 3: 195. 1876

Flowers and fruit unknown: in loose, brownish green tufts with slender, fragile, more or less branching stems up to 4 cm. high; stem-leaves from a conspicous, white, imbricate, oblong-linear or oblanceolate, entire base about 1.5 mm. long, somewhat narrowed to an abruptly spreading nearly straight, setaceous, more or less twisted point two and one half to three times longer, with pale yellowish, cylindric border, entire except at the dentate, acute, or somewhat rounded apex; costa not quite percurrent, smooth on both sides except at the denticulate apex, one half up leaf one third to one fourth the width of leaf, in cross-section showing four guide cells, stereid bands above and below with outer cells not differentiated; cells of upper leaf rather obscure, papillose on both sides, the median about 6 μ wide and 8–10 μ long; cancellinae nearly filling leaf-base, terminating in mostly acute angles. [FIG. 9.]

TYPE LOCALITY: Guadeloupe.

DISTRIBUTION: Porto Rico, Guadeloupe and Martinique.

10. SYRRHOPODON FLAVESCENS C. Müll. Syn. 1: 541. 1849

Syrrhopodon parvulus Schimp. C. Müll. Syn. 1: 544. 1849.

Syrrhopodon Schwaneckeanus C. Müll. Bot. Zeit. 13: 763. 1855.

Syrrhopodon scaber Mitt. Jour. Linn. Soc. 12: 119. 1869.

Syrrhopodon calymperidianus Besch. Ann. Sci. Nat. VI. 3: 19. 1876.*

Syrrhopodon subviridis Besch. Ann. Sci. Nat. VI. 3: 196. 1876.

Syrrhopodon scaber var. *breviligulatus* C. Müll. Hedwigia 37: 235. 1898.

Syrrhopodon breviligulatus C. Müll. Gen. Musc. 370. 1901.

Syrrhopodon Dussii Broth. Symb. Ant. 3: 422. 1903.

Dioicous: in compact yellowish brown to pale green cushions with branching stems, mostly 1–2 cm. high, bearing radicles at their base and often at the base of easily separating branches; stem-leaves when dry erect-spreading, flexuous, 5–12 mm. long, with an oblong-linear base 1–1.5 mm. long, rather gradually narrowed to a linear point three to eight times longer and about one

* Type specimens not seen but belonging here according to the description.

third as wide as the base, with cylindric, yellowish or hyaline border extending all round and entire except at the acute or somewhat rounded, dentate apex; costa not quite percurrent, more or less spiny-dentate near apex on both sides, in cross-section showing four to eight guide-cells with stereid bands above and below, the outer cells on upper side and usually two or three outer cells next guide cells on either side below, differentiated; leaf-cells rather obscure, often slightly elongate, about $6 \times 6\ \mu$–$8 \times 10\ \mu$, with thickened, minutely papillose walls on both surfaces; cancellinae ending above in narrowly acute angles or sometimes somewhat obtuse, nearly filling leaf-base; perichaetial leaves scarcely differing from upper stem-leaves; seta slender, erect, red, 5–8 mm. long; capsule oblong-cylindric, scarcely 1.5 mm. long, with rostrate lid about 1 mm. long; peristome teeth lanceolate, yellowish, papillose, projecting above the mouth about 100 μ, with often indistinct articulations; spores minutely roughened, about 12 μ in diameter; calyptra extending two thirds down capsule, somewhat rough at apex. [FIG. 10.]

TYPE LOCALITY: Trinidad.

DISTRIBUTION: throughout the West Indies and northern South America to Mexico.

11. SYRRHOPODON TENUIFOLIUS (Sull.) Mitt. Jour. Linn. Soc. **12**: 117. 1869

Calymperes tenuifolius Sull. Proc. Am. Acad. **5**: 280. 1861.

Flowers and fruit unknown: in rather loose, pale green to brown tufts with stems mostly under 5 mm. high; stem-leaves from a few millimeters up to over 4 cm. long, from an oblong-linear, entire base about 1.5 mm. long slightly narrowed to a filiform, somewhat grooved point with acute, dentate apex and hyaline or yellowish border of stereid cells entire below the apex; costa not quite percurrent, at apex somewhat rough to spiny-dentate, below on back mostly smooth, on inner side papillose, often to cancellinae, in cross-section showing about six guide-cells with one to three accessory cells on lower side, large stereid bands above and below and outer cells differentiated on upper side only; cells throughout upper part of leaf obscure, mostly angular and slightly elongate, 5–6 μ wide and 6–8 μ long, covered on both sides by more or less compound papillae; cancellinae filling entire base of leaf except a very narrow border above of green cells and terminating above in mostly acute angles. [FIG. 11.]

TYPE LOCALITY: Cuba.

DISTRIBUTION: Cuba, Jamaica and St. Kitts.

None of the specimens examined show propagula, but on the St. Kitts and Jamaican specimens are found young plants, one to three on a leaf, growing from radicles scattered along the leaf point.

12. SYRRHOPODON LYCOPODIOIDES (Sw.) C. Müll. Syn. 1: 538. 1849

Bryum lycopodioides Sw. Prodr. 139. 1788.

Dioicous, male plants more slender than the fertile, bearing several axillary, scattered antheridial buds, the inner perigonial leaves ovate-lanceolate, acute, nearly entire, enclosing numerous antheridia about 0.8 mm. long with few paraphyses: in loose brownish to pale green tufts with somewhat branching stems up to 8–10 cm. high; stem-leaves up to 9 or 10 mm. long, from an oblanceolate, slightly wider, nearly entire, erect base rather gradually narrowed to a spreading, flexuous, linear-lanceolate point with acute apex and bordered all round by a thickened, distantly serrate margin of brown, elongate cells enclosing a small band of stereid cells; costa not quite percurrent, smooth on both sides, about 80 μ wide one half up the leaf and one fifth the width of leaf, in cross-section showing six guide-cells, stereid bands above and below with outer cells differentiated all round; cells of middle and upper blade smooth on both sides, angular, not or slightly elongate, up to 12–14 μ in diameter, in lower leaf and just above the cancellinae often very irregular, transversely or obliquely elongate, with unequally thickened walls; cancellinae mostly broad and somewhat rounded above, filling one half to two thirds the erect leaf-base; perichaetial leaves much like stem-leaves, often longer and extending above the capsule; pedicel about 10 mm. long; capsule ovate-oblong or somewhat spindle-shaped, when dry contracted under the mouth, about 3 mm. long; lid with slender beak about two thirds capsule in length; peristome teeth incurved when dry and not projecting above the mouth, when moist, extending about 80 μ above the rim of capsule, golden brown, very irregular, more or less divided along median line; spores rough, up to 22 μ in diameter; calyptra smooth above. [FIG. 12.]

TYPE LOCALITY: Jamaica.

DISTRIBUTION: Jamaica, Santo Domingo, Guadeloupe, Martinique, Trinidad and northern South America.

ILLUSTRATION: Hedw. Sp. Musc. Suppl. *pl. 40.*

13. SYRRHOPODON RECURVULUS Mitt. Jour. Linn. Soc. 12: 120. 1869

Dioicous, the male plants about like the fertile in habit, with numerous antherieial buds on very short axillary branches or terminal, the outer perigonial leaves about 1 mm. long, the inner one half as long, ovate, acute, costate, serrulate, enclosing about four antheridia without paraphyses: in compact, green mats with conspicuous, white leaf-bases and branching stems 1–2 cm. high; stem-leaves up to 3 mm. long, crispate when dry, from a somewhat oblanceolate or oblong base, ciliate to nearly entire on border, gradually narrowed to a nearly linear or linear-lanceolate point about one and one half times longer, with acute, slightly serrulate apex and pale yellow border entire below the apex, costa nearly percurrent, smooth on both sides except at the dentate or spiny-dentate apex, about 25 μ wide and one sixth width of leaf one half down, in cross-section near middle showing about four guide-cells with stereid bands above and below and outer cells not differentiated; cells throughout upper part of leaf rather distinct, somewhat angular, not or slightly elongate, about 6 μ wide by 6–8 μ long, rather densely papillate and mamillate on both sides of upper leaf, becoming more distinctly mamillate on upper surface just above the cancellinae; cancellinae nearly filling the erect leaf-base, mostly rounded above; perichaetial leaves much like stem-leaves but inner with shorter, green point; pedicel 6–7 mm. long; capsule oblong, about 1.35 mm. long with slender-beaked lid half as long: peristome-teeth golden brown, lanceolate, papillose with rather indistinct articulations, extending about 100 μ above the rim of capsule; spores rough, 12 μ in diameter; calyptra rough above. [FIG. 13.]

TYPE LOCALITY: Cuba.

DISTRIBUTION: known only from Cuba.

EXSICCATI: Wright's Cuban Mosses *47* (as *S. Gaudichaudii*).

Very similar to *S. Gaudichaudii* but more or less ciliate-toothed on upper margin of leaf-base.

14. **Syrrhopodon graminicola** Williams, sp. nov.

Flowers and fruit unknown: in small, dull green tufts with stout, branching, flexuous stems 1–2 cm. high, bearing incurved-imbricate or sometimes spreading flexuous and more or less crispate leaves when dry; upper stem-leaves from an ovate, nearly or quite entire base 0.75–1.4 mm. wide gradually narrowed to an oblong-linear or oblong-lanceolate, acute and apiculate point up to about twice as long, with hyaline border of elongate cells

extending from base to apex, or sometimes nearly or quite disappearing in the upper one fourth of leaf, the border mostly with small, irregular often geminate teeth to near the base; costa percurrent, 50–125 μ wide and about one seventh the width of leaf one half up from base, slightly serrulate on back in upper part and papillose on upper side from near cancellinae half way or more to apex, in cross-section showing about seven guide-cells with stereid bands above and below and outer cells mostly differentiated on upper side; cells throughout upper part of leaf rather indistinct, scarcely elongate, 6–7 μ in diameter, with usually 2–4 minute papillae on either surface; cancellinae broad, not entirely filling the basal part of leaf, terminating above in mostly acute angles; older stem-leaves often with numerous, slender, cylindrical propagula, 200 to 300 μ long, with about twelve cross-walls, growing from cells of blade near either side of costa a little above the cancellinae on the upper surface of leaf and extending half way or more to the apex. [FIG. 14.]

TYPE collected in Jamaica, growing on bamboo joints, Woodstock, Westmoreland Hills, September, 1907, *E. G. Britton 579* (herbarum of the New York Botanical Garden).

DISTRIBUTION: known only from the type locality and Sierra Nipe, Cuba.

This is somewhat like *S. flexifolius* Mitt., but the cells are smaller, more obscure, less elongate, and densely papillose—not smooth or nearly so, as in *S. flexifolius*.

15. SYRRHOPODON ELONGATUS Sull. Proc. Am. Acad. 5: 280. 1861

Evidently dioicous, male flowers not found: in tall, compact, pale green to brown tufts with erect stems up to 12 cm. high, often bearing at the apex two to four short, fruiting branches with spreading-flexuous to somewhat squarrose leaves from a conspicuous, imbricate, whitish base and abundant tomentum on both stems and leaves; leaves of stem and branches, from an oblong base about 2 mm. long, somewhat spiny-dentate above, narrowed to a recurved, grooved, twisted and flexuous or nearly straight point about 3 mm. long, spiny-dentate above and slightly serrulate on the pale, cylindric border below to the enlarged base; costa excurrent into a thorn-point, about 50 μ wide near the middle, smooth on inner face, spiny-dentate about one half down on the back, in cross-section showing four guide-cells, stereid bands above and below, with outer cells not differentiated; cells throughout upper part of leaf distinct, roundish or slightly elongate,

8–9 μ in diameter, highly mamillose on both sides and more or less minutely papillose with three or four papillae to each cell surface; cancellinae nearly filling the erect base, mostly broad and rounded above; inner perichaetial leaves rather smaller than outer, with base yellowish; seta 15–18 mm. long; capsule oblong-cylindric, small-mouthed, about 2.5 mm. long; peristome-teeth projecting above mouth 125 μ, lanceolate, golden brown, rough, with rather indistinct articulations; spores rough, about 16 μ in diameter; lid with beak about 1.5 mm. long; calyptra descending over one half down capsule, rough in upper half. [FIG. 15.]

TYPE LOCALITY: Cuba: *Wright 49*, sterile specimens (fruit described from specimens collected in 1910 near Woodford, Sierra Nipe, Oriente, *J. A. Shafer 3733*.)

DISTRIBUTION: known only from Cuba.

16. SYRRHOPODON TEXANUS Sull. Musci U. S. 103. 1856

Syrrhopodon alabamensis Lesq. & Schimp.; Jaeger, Ber. St. Gall. Nat. Ges. **1877–78**: 413. 1879.

Male plants unknown: in pale green to dusky green cushions with simple or slightly branching stems 2–3 cm. high; stem-leaves more or less crispate and tubulose when dry, erect-spreading when moist, the upper about 4 mm. long, linear-lingulate (or above often consisting of little more than the stout, very rough costa if bearing propagula), from a somewhat broader, ovate base, one fourth or more the entire length, with apex obtuse, often spiny-dentate, and border of leaf pale, irregularly dentate to spiny-dentate almost to the insertion of leaf; costa stout, 90–125 μ in diameter below, vanishing just below apex, very rough on back to below the cancellinae, with irregular, low, somewhat forking or spinose papillae; leaves in cross-section showing a terete costa with six or seven guide-cells, thick stereid bands above and below and differentiated outer cells, the leaf-blade mostly mamillose and finely papillose on upper side, papillose on under side, the margin a cylindrical band of minute, stereid cells extending from a little below the apex to near the cancellinae; cells of lamina variable, mostly roundish, obscure, 6–7 μ in diameter in upper leaf to somewhat pellucid and larger below, at least near the cancellinae; cancellinae either acute or somewhat rounded at apex, the cells toward costa broad, often nearly square; perichaetial leaves very similar to upper stem-leaves; seta erect, 1–2 cm. long; capsule ovate-cylindric, contracted at mouth, about 2 mm. long, with slender-beaked lid nearly as long; peristome-teeth short, lanceolate, obtuse, with two or three prominent articulations; calyptra de-

scending to base of capsule, scabrous one third down from apex; spores minutely punctate, about 14 μ in diameter. [FIG. 16.]

TYPE LOCALITY: Texas.

DISTRIBUTION: Texas to Florida and Georgia.

17. SYRRHOPODON LIGULATUS Mont. Syll. 47. 1856

Syrrhopodon crispus Aust. Bot. Gaz. 2: 109. 1877.

Growing in compact, brownish green tufts with mostly simple stems up to 1.5 cm. high; stem-leaves with conspicuously white, imbricate base, crispate above when dry, 2–2.5 mm. long from an obovate-lanceolate base, entire to somewhat serrulate in upper part, slightly narrowed to a lingulate, grooved point, from scarcely as long to about one and one half times longer than the base, with rounded apex and margin crenulate-papillose with short green cells except in lower part, where a narrow, hyaline border of elongate cells is usually present; costa nearly or quite percurrent, slightly serrulate on back toward the apex, smooth below, about one eighth the width of leaf half way up, in cross-section showing toward the base four guide-cells, in upper half mostly two or three guide-cells with stereid bands above and below and no differentiated outer cells, the upper stereid band small, often of only three or four cells; cells of upper blade mostly obscure, not elongate, 6–8 μ in diameter, mamillate and densely papillose on both sides; cancellinae nearly filling the enlarged base, mostly broad and rounded above; perichaetial leaves about like those of the stem; seta 3–4 mm. long; capsule ovate, scarcely 1 mm. long; peristome teeth golden brown, projecting well above the mouth, rather rough, with indistinct articulations; spores rough, 12–15 μ in diameter; lid and calyptra not seen. [FIG. 17.]

TYPE LOCALITY: Guiana.

DISTRIBUTION: Florida, Guadeloupe and Guiana.

18. SYRRHOPODON PARASITICUS (Sw.) Besch. Ann. Sci. Nat. VIII. 1: 298. 1895

Bryum parasiticum Sw. Prodr. 139. 1788.

Encalypta parasitica Sw. Ind. Occ. 1759. 1806.

Calymperes parasiticum Hook. & Grev. in Brewster, Edinb. Jour. Sci. 1: 131. 1824.

Dioicous, the male plants with often two or three rather conspicuous, scattered buds, the inner perigonial leaves very short, broadly ovate-acute, enclosing numerous antheridia about 0.33 mm. long, without paraphyses: plants scattered or in loose tufts

with stems up to 2 cm. high; stem-leaves usually 4–5 mm. long and about 0.65 mm. wide, nearly linear, the basal part often slightly narrower than the upper part, or the terminal leaves at times much shorter and broader, somewhat lanceolate, up to 1 mm. wide, all rather gradually acutely pointed, subtubulose and erect-flexuos when dry, widely spreading, almost squarrose when moist, with a pale, minutely serrulate or entire border of elongate, stereid cells (sometimes quite lacking in the apical leaves) extending from about one third below the apex to four fifths way down the leaf; costa nearly percurrent, smooth on the back except at the slightly denticulate apex, about 60 μ wide near the apex of the cancellinae, in cross-section showing three or four guide-cells, stereid bands above and below them and outer cells not differentiated in the upper part, but more or less differentiated on the ventral side in the lower costa; cells in upper part of blade mamillose on the upper, smooth or unipapillate on the under side, mostly hexagonal and not elongate or slightly so, the median about 8 μ wide by 8–10 μ long, those next the costa on upper side often bearing, from some distance below the apex to near the cancellinae filiform propagulae about 0.5 mm. long, with fifteen to twenty cross-walls; cancellinae filling the most of the leaf-base and terminating in narrow angles next the costa one fourth to one third way up the leaf; perichaetial leaves scarcely differentiated; seta 2–2.5 mm. long, bearing an erect, cylindric capsule about 1.5 mm. long; median exothecal cells more or less four-to-six-sided, 20–25 μ in diameter, with thick walls; peristome and lid not seen; calyptra (immature and not fissured) with rather narrow base, gradually tapering upward and rough throughout. [FIG. 18.]

TYPE LOCALITY: Hispaniola (Hayti).

DISTRIBUTION: Cuba (*E. G. Britton 5040a*; *Brother Leon 3564*), Hayti, Porto Rico (*5197, E. G. Britton*), Trinidad and Yucatan.

ILLUSTRATION: Schwaegr. Suppl. 2^2: *pl. 17*.

Known only from the original collection until obtained in Cuba by Mrs. Britton. The type specimens do not seem to show any propagula, but these bodies readily fall off as the leaves become older. The species is quite closely related to the South American *S. flexifolius* Mitt., which has similar propagula, but the latter has larger leaf-cells and a border extending nearer to both the base and the less acute apex while the cancellinae do not form so narrow an angle upward.

Lindberg* has given a rather full description of this species and

* Öfv. Kongl. Vet. Akad. Forh. 21: 604–5. 1864.

considers it to be dioicous; he retains it under *Calymperes* although describing a peristome of sixteen teeth that hardly project above the rim of the capsule, a pale, narrow border as in *Syrrholodon* and a calyptra split on one side; a sterile specimen is also mentioned as bearing filiform propagula as in the recent collections; the lid is said to be subulate and as long as the capsule, but both mature lids and calyptras seem to be unknown in any available collection.

19. **Syrrhopodon filigerus** (Aust.) Williams, comb. nov.

Calymperes filigera Aust. Bot. Gaz. 4: 151. 1879.

Flowers and fruit unknown: in thin, dusky green mats with stems 6–8 mm. high; leaves mostly 2.5–3.5 mm. long, incurved or crispate when dry, from a narrowed, more or less oblong, base becoming slightly wider upward to a point about three fourths up leaf, then gradually narrowing to the broadly acute apex, the leaf-blade somewhat keeled and borders flat and entire or nearly so; costa vanishing in apex, 40–50 μ wide about one half up and one tenth the width of the leaf, sometimes bearing numerous filiform propagula from near the middle half way up to apex; costa in cross-section somewhat semiterete, with six or seven guide-cells, stereid bands above and below them and without differentiated outer cells; the cells of leaf-blade mamillose on upper side, finely papillose on under side; border of leaf scarcely extending above the middle, often more or less wanting below, composed of a pale, cylindric band of elongate, stereid cells; cells of blade pellucid, mostly slightly elongate, somewhat angular, the median 7–8 μ wide and 8–10 μ long; cancellinae often extending two fifths up leaf and terminating next the costa in very acute angles. [FIG. 19.]

TYPE LOCALITY: Caloosa, Florida.

DISTRIBUTION: known only from the type locality.

This species is nearly related, by the position of the propagula and shape of leaf, to *S. parasiticus*, but the latter is a larger plant with much wider leaves and costa.

Note.—*S. circinatus* Schimp. is *Symblepharis Schimperianum* (Paris) Card.; *S. crispatus* Hampe is *Didymodon campylocarpus* C. Müll.; *S. fragilis* Hampe is *Trichostomum Schlimii* C. Müll.; *S. strigosus* (Brid.) Mitt., probably does not belong to the Calymperaceae, but the type does not seem to be known in Berlin.

CALYMPERES Sw. (?Weber f. Tab. Calypt. Operc. 1813) in Schwaegr. Suppl. 1[2]: 333. 1816

Dioicous: plants mostly of medium size, growing in compact tufts with erect, often dichotomous stems, radiculose at the base. Stem-leaves when dry mostly strongly incurved or crispate and subtubulose above the erect, clasping, usually broader and conspicuously white base, the leaf-point varying from lanceolate to lingulate or ligulate with apex often broad. Costa stout, vanishing just below the apex or more or less excurrent, often enlarged and bearing propagula in dense clusters at the apex, from smooth to rough on both sides, sometimes spinose, in cross-section showing from one to three rows of guide-cells with stereid bands above and below and outer cells mostly differentiated. Leaf-margin usually more or less thickened and serrate or sometimes with two serrate wings. Ribbon-like bands of green, elongate cells (teniolae), occasionally wanting, extend just within the margin from base to near apex in some species, in others only for a short distance in the upper basal part of leaf. Cells of upper blade roundish to angular, sometimes shortly elongate, chlorophyllose, often rather obscure, mostly mamillose on upper side and smooth to somewhat mamillose and often papillose on under side; hyaline, rectangular or nearly square cells (cancellinae), usually filling most of basal or sheathing part of leaf, except a narrow border, and changing abruptly into the green cells of blade above (except in *S. fluviatile* which lacks cancellinae). Peristome none. Capsule oblong to cylindric, smooth, on an erect, more or less elongate seta. Calyptra persistent, plicate, rough in upper part, embracing the base of capsule and split on sides only part way down to the base. [PLATE 17.]

Type species: *Calymperes lonchophyllum* Schwaegr.

With cancellinae; teniolae usually present.
Leaf-cells not transversely elongate throughout blade above cancellinae; the spreading blade more or less crispate when dry and not more than 3 or 4 times longer than clasping basal part; guide-cells of costa in one row except in *C. cubense*.
Leaf-margin distinctly serrulate throughout upper part of leaf or entire and basal part somewhat serrulate.
Teniolae extending to or above the middle of leaf.
Green cells of blade mostly up to 7 or 8 μ in diameter and in about forty rows or less from costa to margin in widest part of leaf.
Mamillose cells not terminating in small papillae; teniolae only two or three

cells in from margin in upper basal part of leaf; cancellinae mostly broad and rounded above.
Costa as wide or wider at the base than half way up. 1. *C. Richardi.*
Costa about one half as wide at the base as half way up. 2. *C. cubense.*
Mamillose cells terminating in one or two small papillae; teniolae four to eight cells in from margin in upper basal part.
Cancellinae terminating in acute angles next costa; leaf-base not much broader than blade above. 3. *C. emersum.*
Cancellinae terminating in broad angles or rounded above; leaf-base two or three times wider than blade above. 4. *C. disciforme.*
Green cells of blade about 4 μ in diameter, in fifty to one hundred rows in widest part of of leaf; teniolae usually six to twelve cells in from margin in lower leaf and distinct to insertion of leaf. 5. *C. Donnellii.*
Teniolae very short or wanting, only found in upper basal part of leaf when present.
Upper side of costa rough to near cancellinae and teniolae present. 6. *C. nicaraguense.*
Upper side of costa smooth except near apex and teniolae wanting. 7. *C. Heribaudi.*
Leaf-margin entire above and below or slightly serrulate near apex only.
No teniolae; costa rough on both sides to below the middle. 8. *C. Nashii.*
Teniolae short, but usually distinct in upper base; costa smooth, or nearly so, to apex. 9. *C. Guildingii.*
Leaf-cells distinctly transversely elongate except in the small basal part; the spreading leaf-blade nearly straight or somewhat flexuous, rarely somewhat crispate, eight to fifteen times longer than the narrow clasping base; guide-cells of costa in two or three rows.
Leaves up to 15 or 18 mm. long; teniolae mostly more or less evident in basal part; stems under 6 mm. long. 10. *C. lonchophyllum*
Leaves up to 8 or 10 mm. long; teniolae wanting; stems usually much more than 6 mm. high. 11. *C. Levyanum.*
Without cancellinae; teniolae finely developed. 12. *C. fluviatile.*

1. CALYMPERES RICHARDI C. Müll. Syn. 1: 524. 1849

Calymperes Breutelii Besch. Ann. Sci. Nat. VIII. 1: 278. 1895.
Calymperes guadalupense Besch. Ann. Sci. Nat. VIII. 1: 285. 1895.

Calymperes hexagonum Besch. Ann. Sci. Nat. VIII. 1: 286. 1895.
Calymperes Hookeri Besch. Ann. Sci. Nat. VIII. 1: 287. 1895.
Calymperes panamae Besch. Ann. Sci. Nat. VIII. 1: 298. 1985.

In compact cushions with sometimes branching stems 5–6 mm., or rarely up to 2 cm. high; leaves strongly incurved or crispate when dry, the lower short, ovate, about 0.75 mm. wide by 1.5 mm. long, the upper 3–3.5 mm. long, from a variable base, sometimes distinctly ovate or obovate and considerably wider than blade above, sometimes scarcely or not wider than above, and extending into a broadly acute or obtuse point, or those leaves bearing propagulae narrowed above to a stout point without distinct blade and of variable length, with rounded apex; leaf-margin entire except along upper part of clasping base, which is more or less irregularly serrulate; costa stout, vanishing just below apex, rough on both sides above, slightly rough or smooth below the middle and bearing often on upper side at apex a dense cluster of narrowly spindle-shaped propagula, up to 250 μ long with ten to fifteen cross-walls; cells of upper leaf mamillose, distinct, mostly roundish, 6–8 μ in diameter; teniolae two or three cells wide and one to five cells in from lower margin, extending nearly three fourths up leaf and running into the thickened border of upper leaf; cancellinae extending one third to one fourth up leaf, broad, mostly rounded above; perichaetial leaves much like stem-leaves but larger below with cancellinae extending higher up; seta erect, about 3 mm. long; capsule 1.5 mm. long, elongate-oval, smooth, without peristome; lid short-rostrate; calyptra persistent, plicate, rough toward apex, clasping the seta below capsule and split mostly along the middle on one side; spores rough, up to 35 μ in diameter. [FIG. 1.]

TYPE LOCALITY: Guiana.

DISTRIBUTION: Florida, Panama and the West Indies to Brazil.

2. **Calymperes cubense** Williams, sp. nov.

Evidently dioicous: growing in compact tufts with mostly simple stems 6–8 mm. high; stem-leaves up to 3 mm. long, from a white, appressed, more or less obovate or obcuneate base rather gradually or somewhat abruptly narrowed into an oblong-linear to lanceolate, more or less acute point from shorter to about one and one half times longer than the basal part, the margins serrulate nearly all round and the point more or less crispate when dry; costa not quite percurrent, very rough on both sides to near the base, widest, 100 μ or more, about half way up and tapering to a base about one half as wide, in cross-section near the middle

showing about two rows of guide-cells with an indefinite number of smaller accessory cells and stereid cells in one or two rows at the upper and under surface; leaf-cells pale throughout, very mamillose on the upper surface and smooth or papillose on the under side to the cancellinae, the median cells hexagonal to roundish, about 8 μ in diameter; teniolae one to three cells in from the margin, usually extending from the upper part of the base of the leaf to above the middle, and consisting of a double thickness of one or two rows of elongate, often highly mamillose cells; cancellinae mostly broad and more or less rounded above; inner perichaetial leaves rather longer than stem-leaves and with a smaller base, the archegonia and filiform paraphyses numerous; obclavate, eight- to ten-celled propagula sometimes occur in clusters at the apex of the costa. [FIG. 2.]

TYPE collected in the Sierra de Gavilanes, Santa Clara Province, Cuba, August, 1906, *Brothers Leon & Clement 6773* (herbarium of the New York Botanical Garden).

The peculiar cross-section of the leaf of this species is very similar to that of *C. Dozyanum* Mitt. of Java.

3. CALYMPERES EMERSUM C. Müll. Bull. Herb. Boiss. 5: 189. 1897

In broad, lax, dull-green tufts with stems about 1.5 cm. high; stem-leaves about 4 mm. long, mostly incurved, scarcely crispate when dry, from a somewhat wider, or in the lower leaves narrower, oblong or obovate, serrulate base extending into a broad, oblong-linear point, from not much longer than basal part to about twice longer, with rather abruptly acute, serrulate apex and costa vanishing just below apex or when bearing propagulae, excurrent and enlarged into a stout rough point with the propagulae on all sides near apex; costa in middle of leaf about one tenth the width of leaf, rough on both sides in upper half, in cross-section showing four to six guide-cells, stereid bands above and below and outer cells differentiated on both sides; blade of leaf highly mamillose and papillose on upper side, the under side not mamillose but finely papillose; cells throughout spreading leaf-blade distinct, scarcely or not elongate, angular to roundish, 7–8 μ in diameter, with one or sometimes two papillae on each surface; teniolae extending from or near the base to near the abruptly narrowed apex and only one or two cells in from margin in upper leaf, and four to eight cells in from margin at the broadest basal part; cancellinae often extending nearly one half up leaf next costa and terminating in acute angles; "theca hardly emergent, calyptra finely roughened at apex."—*C. Müller.* [FIG. 3.]

TYPE LOCALITY: Guatemala.

DISTRIBUTION: known only from the type locality and Deering Hammock, Cutler, Dade County, Florida, 1916, *J. K. Small.*

4. CALYMPERES DISCIFORME C. Müll. Linnaea **21**: 183. 1848

Calymperes Wulfschlaegelii Lorentz, Moosst. 168. 1864.

In dull or brownish green cushions with somewhat branching stems up to 1.5 cm. high; leaves, when dry, tubulose and crispate above, on lower stem about 2 mm., on upper stem 3.5 mm. long, from a broad, usually obovate, whitish, clasping base narrowed to a broadly lingulate or linear point one and one half to two times longer, with apex broadly acute or in those leaves bearing propagulae, with apex more elongate and narrowed; leaf-margin finely serrulate, nearly to base, thickened above; costa not quite percurrent or somewhat enlarged above and excurrent, rough on both sides to cancellinae or smoothish in lower part, in cross section showing about 6 guide-cells with stereid bands above and below and outer cells differentiated on upper side; leaf-cells above the cancellinae mostly 7 or 8 μ in diameter, slightly or not elongate, mamillose on both sides with more or less distinct papillae on upper blade; teniola extending to above middle of leaf, about 8 cells in from margin in upper basal part of leaf and 2 or 3 cells in from margin of blade above; cancellinae extending one third to two-fifths up leaf, broadly angular, often rounded above; perichaetial leaves about like upper stem-leaves; seta 4 or 5 mm. long; calyptra persistent, striate, very rough above. [FIG. 4.]

TYPE LOCALITY: Surinam.

DISTRIBUTION: Santo Domingo; also in northern South America. The Florida specimens which have been referred to the above belong either to *C. Richardi* or to *Syrrhopodon filigerus.*

5. CALYMPERES DONNELLII Aust. Bot. Gaz. **4**: 151. 1879

Calymperes rufescens Besch. Ann. Sci. Nat. VIII. **1**: 266. 1895.

Calymperes Brittoniae Besch. Ann. Sci. Nat. VIII. **1**: 278. 1895.

Syrrhopodon Smithii Besch. in Paris, Index, ed. 1, 1255. 1898.

Calymperes portoricense Ren. & Card. Bull. Soc. Bot. Belg. **41**[1]: 57. 1904.

In extensive, green mats with stems from 3 mm. to 1 cm. high; leaves incurved or crispate when dry, the lower 2.5–3 mm. long, the upper about 5 mm. long, from a mostly slightly broader, more

or less ovate base one third to one fourth the entire length of leaf extending into an oblong-linear blade with broadly acute apex, or those bearing propagulae usually abruptly narrowed to a rough, stout point of variable length; leaf-margins incurved, doubly and irregularly serrate above, with thickened margin, below minutely serrulate; costa stout, often very rough on inner face above, and on back from apex to near the cancellinae, in cross-section showing about seven guide-cells with large stereid bands above and below and outer cells differentiated on both surfaces; cells throughout upper leaf mamillose and papillose, roundish, mostly 4–5 μ in diameter; teniolae distinct to the insertion of leaf, eight to twelve cells in from marign in broadest part of leaf, extending about one half up leaf and disappearing in the thickened border; cancellinae extending one third to one fourth up leaf, mostly terminating above in acute angles and composed of square to short rectangular cells; perichaetial leaves few, only about one half as long as upper stem-leaves, enclosing numerous, very long paraphyses; seta dark red, erect, 5 mm. long; capsule cylindric, about 2 mm. long; calyptra scabrous above; spores rough, about 18 μ in diameter. [FIG. 5.]

TYPE LOCALITY: Caloosa, Florida.

DISTRIBUTION: Florida (sterile), Cuba, Jamaica (fertile), Porto Rico and northern South America (Mt. Guayrapurina, *Spruce*, in Mitten Herbarium, fertile).

6. CALYMPERES NICARAGUENSE Ren. & Card. Bull. Soc. Bot. Belg. 33^2: 117. 1894

Calymperes Carionis C. Müll. Bull. Herb. Boiss. 5: 189. 1897.

In broad, dusky green cushions with stems 1.5–2.5 cm. high, bearing crowded leaves up to 4.5 mm. long, crispate when dry; stem-leaves from a broadly obovate or obcuneate base with margins mostly serrulate, abruptly narrowed to a nearly linear point two or three times as long, with thickened, slightly serrulate border and serrulate, blunt apex; upper surface of leaf highly mamillose, under surface nearly smooth or somewhat papillose; costa not quite percurrent, often rough on both sides in upper half, mostly smooth below; leaf in cross-section near middle showing a semiterete costa with eight or ten guide-cells, stereid bands above and below, with outer cells differentiated and a leaf-border of a nearly cylindric band of rather small, not stereid cells; cells throughout upper part of leaf rather distinct, somewhat angular or roundish, the median about 6 μ in diameter; teniolae mostly quite distinct, eight or ten cells in from margin, extending

from the lower extremity of the thickened border for only a short distance downward into the basal part of leaf; cancellinae very broad above, mostly terminating in broadly acute angles or somewhat rounded at the apex, scarcely as long as leaf-base; seta erect, 5–6 mm. long; capsule about 2.5 mm. long, cylindric; calyptra persistent, very rough above; spores rough, up to 20 μ in diameter. [FIG. 6.]

TYPE LOCALITY: Nicaragua.

DISTRIBUTION: Nicaragua and Guatemala.

7. CALYMPERES HERIBAUDI Paris & Broth. in E. & P. Nat. Pfl. I^3: 1189. 1909

In dark green cushions with stems about 1 cm. high; leaves flexuous or crispate when dry, up to 5 mm. long, from an ovate base about 1.5 mm. long with margins finely serrulate in upper half and mostly entire below, narrowed to a point two to three and one half times longer with thickened, somewhat doubly serrulate border extending from basal part to a little below the mostly blunt and serrulate apex; leaf-surface on upper side highly mamillose, on under side nearly smooth below and mostly papillose above; costa vanishing just below apex, smooth below, rough and often bearing propagulae on upper side near apex; cross-sections near middle of leaf show eight or nine guide-cells, stereid bands above and below, with outer cells differentiated, the blade of one layer of cells and a border of a cylindrical band of six to nine cells enclosing one or two stereid cells; cells throughout upper leaf mostly square to roundish, the median 6–7 μ in diameter; teniolae wanting; cancellinae usually extending highest up next costa and terminating in acute angles; fruit unknown. [FIG. 7.]

TYPE LOCALITY: Panama near David.

DISTRIBUTION: known only from the type locality.

This species is much like *C. nicaraguense* but has rather longer leaves, the basal margin more entire and without teniolae; also the thickened border contains a few stereid cells that seem to be wanting in *C. nicaraguense*, and the costa is mostly smooth on upper side.

8. **Calymperes Nashii** Williams, sp. nov.

In very thin, dusky green cushions or somewhat gregarious, with stems only 2 or 3 mm. high; leaves strongly incurved or crispate when dry, about 2.5 mm. long, oblong-linear from a slightly broader or not broader base; leaf entire with a thick,

cylindric border of short-rectangular, green cells extending from a little below the apex to the erect or clasping basal part; costa nearly cylindric, about 65 μ wide one third up from base, papillose on both sides to cancellinae, usually shortly excurrent, slightly enlarged at the apex and bearing numerous, short, spindle-shaped propagula about 120 μ long, with six to eight transverse walls; cross-sections of costa show about four guide-cells, stereid bands above and below of rather large cells, and outer cells differentiated on upper side; leaf-cells of spreading blade mostly not elongate, the median 4–6 μ in diameter, mamillose on upper side, slightly or not mamillose but more or less papillose on under side; teniolae wanting; cancellinae extending about one fourth up leaf, truncate or somewhat rounded above, mostly four to six rows of cells wide on either side of costa and extending about one half way from costa to margin with the small green cells of blade above descending on outer side in a broad band to or near base; fruit unknown. [FIG. 8.]

TYPE collected in Hayti on trees at sea-level near Port Margot, August, 1903, *G. V. Nash 51* (herbarium of the New York Botanical Garden).

DISTRIBUTION: Hayti, Mona Island and Florida (on hammocks, Adams Key, Dade County, March, 1915, *Small & Mosier 5158*).

This species is much like some of the small forms of *C. Richardi* growing in similar situations, but teniolae are entirely wanting, the leaf-border is entire and the cancellinae are narrower.

9. CALYMPERES GUILDINGII Hook. & Grev. in Brewster, Edinb. Jour. Sci. 3: 223. 1824

Syrrhopodon badius Schimp.; Besch. Ann. Sci. Nat. VI. 3: 197. 1876.

Calymperes guadeloupensis Broth. Symb. Ant. 3: 423. 1903.

In large tufts or mats with stems up to 3–4 cm. high; stem-leaves 4–5 mm. long, flexuous or crispate when dry, erect-spreading when moist, from an ovate or obovate, mostly much broader base narrowed to a linear-lanceolate point about three times longer, the upper surface mamillose, the under smooth, with leaf margins entire or nearly so all round and much thickened from apex to the clasping base; costa stout, nearly percurrent, smooth on both sides, often with propagulae on upper side near apex; cross-sections of leaf near middle show a nearly semiterete costa with five or six guide-cells, stereid bands above and below and outer cells differentiated, with a nearly cylindrical leaf-border composed

of three to five stereid cells surrounded by seven or eight larger outer cells; leaf-cells throughout upper blade distinct, slightly elongate, 6–7 μ wide by 8–10 μ long; teniolae usually distinct in upper part of clasping base, four to eight cells in from margin, merging into the elongate cells of border toward base of leaf and upward soon terminating in the thickened leaf-border; cancellinae extending about one fourth up leaf, mostly terminating in acute angles or sometimes rounded or truncate; perichaetial leaves about like stem-leaves but with higher clasping base and green cells extending more or less downward between the cancellinae and costa; seta erect, 4–5 mm. long; capsule 2 mm. long, cylindric, with conical, short-beaked lid; calyptra plicate, scabrous above. [FIG. 9.]

TYPE LOCALITY: St. Vincent, British West Indies.

DISTRIBUTION: St. Kitts, Guadeloupe, St. Vincent, and Porto Rico.

EXSICCATI: Husnot, Pl. des Antilles, *135*, *195*.

10. CALYMPERES LONCHOPHYLLUM Schwaegr. Suppl. 1²: 333. 1816

Syrrhopodon venezuelanus Mitt. Jour. Linn. Soc. 12: 125. 1869.
Calymperes asperipes Besch. Ann. Sci. Nat. VIII. 1: 277. 1895.

Dioicous, male plants much like the fertile plants, bearing several oblong flowers about 1 mm. long in the axils of the upper leaves, the perigonial leaves one half to three fourths mm. long, more or less ovate, acutely pointed, pale, costate, slightly serrulate above and enclosing five or six antheridia 0.4 mm. long with quite numerous, longer paraphyses: in low mats with tomentose stems mostly 3–5 mm. high, bearing crowded, ligulate, flexuous, rarely crispate leaves up to 15–18 mm. long; stem-leaves from a narrowly oval base with serrulate margins 0.75–1.5 mm. long, extending into a point ten to fifteen times longer, mostly slightly wider above than below, with thickened, doubly serrulate or sometimes nearly entire borders and acute, serrulate apex; costa nearly percurrent, smooth on both sides, without propagula; cross-sections of leaf about one half down show ten or twelve guide-cells in costa with accessory cells in one or two rows, stereid bands above and below, with outer cells differentiated, and leaf-blade often of a double layer of cells extending from costa to the thick, three-sided border; leaf-cells throughout spreading blade transversely elongate, mostly 4–5 μ by 6–8 μ, smooth on both sides; teniolae not extending into narrowed blade, and from distinct to almost or quite wanting in basal part; cancellinae nearly filling the basal

part of leaf, mostly rounded or truncate above; outer perichaetial leaves much like stem-leaves but the base larger and irregularly serrate or incised above, enclosing a few very small inner leaves and numerous paraphyses; seta 10–12mm. long, often bent, slightly rough in upper half; capsule 2 mm. long; lid with beak one half the capsule in length; spores rough, up to 20 μ in diameter. [FIG. 10.]

TYPE LOCALITY: Guiana.

DISTRIBUTION: Martinique, Guadeloupe, Jamaica, Central and northern South America.

ILLUSTRATION: Schwaegr. Suppl. *pl. 98.*

11. CALYMPERES LEVYANUM Besch. Ann. Sci. Nat. VIII. 1: 290. 1895.

In habit somewhat like *C. lonchophyllum*, but stems longer, 1 cm. or more, and leaves shorter, 8–10 mm. long; stem-leaves from an oblong base, serrulate on margins, about 1 mm. long, narrowed into a ligulate-spatulate point six to eight times longer with broad, mostly acute, serrulate apex and thickened border serrulate above, becoming nearly or quite entire below the middle; costa not quite percurrent, smooth on both sides except near apex; leaves in cross-section showing costa with eight or ten guide-cells, an accessory row of four to five cells, stereid bands above and below with differentiated outer cells, and a leaf-blade of one layer of cells, with a cylindric to three-sided border of eight to ten rows of cells; leaf-cells rather obscure in upper leaf, roundish to slightly transversely elongate, mostly 3–4 μ in diameter and from nearly smooth to minutely papillose on both sides teniolae wanting; cancellinae nearly filling the ovate base, of mostly square cells, at apex rounded or sometimes acutely angled; fruit unknown. [FIG. 11.]

TYPE LOCALITY: Nicaragua.

DISTRIBUTION: known only from the type locality and Cuba.

12. **Calymperes fluviatile** Williams sp. nov.

Flowers and fruit unknown: growing in rather stiff, dark green, loose mats; stems simple, 2–3 cm. long, with inconspicuous radicles; in cross-section somewhat triangular, about 250 μ in diameter, showing a distinct central strand and outer walls composed of about three rows of thick-walled cells; leaves when dry subtubulose and incurved or somewhat crispate, when moist widely spreading, oblong-lingulate, entire, 3–3.5 mm. long by a little over 1 mm. wide about half way up the leaf, somewhat

rounded to the scarcely acute apex and with very distinct teniolae of three or four thicknesses of cells and five or six cells wide extending from some little distance above the base to about an equal distance below the apex, with three to six rows of cells between the tenola and margin; costa about 100 μ wide a little above the base, nearly percurrent, in cross-section, showing five or six guide-cells, large stereid bands above and below them and outer cells somewhat differentiated; cells of blade in upper leaf mostly roundish or slightly elongate, mamillose on the ventral, flat on the dorsal side, the median cells 6–7 μ in diameter, gradually changing toward the base to the not very numerous rectangular cells which are more or less colored and never form distinct cancellinae. [FIG. 12.]

TYPE collected in the vicinity of Utuado, Porto Rico, on wet rocks, March, 1915, *E. G. Britton 5206* (herbarium of the New York Botanical Garden).

DISTRIBUTION: known only from type locality and La Juanita, near Las Marias, Porto Rico.

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Explanation of Plates 15-17

PLATE 15

Cross-sections of *Syrrhopodon* made about halfway down the leaf.

FIG. 1. *Syrrhopodon rigidus* Hook. & Grev., from St. Vincent, × 235.
FIG. 2. *Syrrhopodon Bernoullii* C. Müll., from Panama, × 235.
FIG. 3. *Syrrhopodon floridanus* Sull., from Bermuda, × 235.
FIG. 4. *Syrrhopodon incompletus* Schwaegr., from Cuba, × 235.
FIG. 5. *Syrrhopodon Berterianus* (Brid.) C. Müll., from Hayti, × 350.
FIG. 6. *Syrrhopodon martinicensis* Broth., from Guadeloupe, × 235.
FIG. 7. *Syrrhopodon Gaudichaudii* Mont., from Isle of Pines, × 235.
FIG. 8. *Syrrhopodon inflexus* Mitt., from Colombia, × 235.
FIG. 9. *Syrrhopodon Husnoti* Besch., from Martinique, × 235.
FIG. 10. *Syrrhopodon flavescens* C. Müll., from Trinidad, × 235.

PLATE 16

Cross-sections of *Syrrhopodon* made about half way down the leaf.

FIG. 11. *Syrrhopodon tenuifolius* (Sull.) Mitt., from Jamaica, × 235.
FIG. 12. *Syrrhopodon lycopodioides* (Sw.) C. Müll., from Jamaica, × 235.
FIG. 13. *Syrrhopodon recurvulus* Mitt., from Cuba, × 235.
FIG. 14. *Syrrhopodon graminicola* R. S. Williams, from Jamaica, × 350.
FIG. 15. *Syrrhopodon elongatus* Sull., from Cuba, × 235.
FIG. 16. *Syrrhopodon texanus* Sull., from Texas, × 235.
FIG. 17. *Syrrhopodon ligulatus* Mont., from Florida, × 350.
FIG. 18. *Syrrhopodon parasiticus* (Sw.) Besch., from Hayti, × 235.
FIG. 19. *Syrrhopodon filigerus* (Aust.) R. S. Williams, from Florida, × 350.

PLATE 17

Cross-sections of *Calymperes* made about halfway down the leaf.

FIG. 1. *Calymperes Richardi* C. Müll., from Guiana, × 200.
FIG. 2. *Calymperes cubensis* R. S. Williams, from Cuba, × 200.
FIG. 3. *Calymperes emersum* C. Müll., from Guatemala, × 300.
FIG. 4. *Calymperes disciforme* C. Müll., from Surinam, × 200.
FIG. 5. *Calymperes Donnellii* Aust., from Florida, × 300.
FIG. 6. *Calymperes nicaraguense* Ren. & Card., from Nicaragua, × 200.
FIG. 7. *Calymperes Heribaudi* Paris & Broth., from Panama, × 200.
FIG. 8. *Calymperes Nashii* R. S. Williams, from Hayti, × 300.
FIG. 9. *Calymperes Guildingii* Hook. & Grev., from St. Vincent, × 200.
FIG. 10. *Calymperes lonchophyllum* Schwaegr., from Guadeloupe, × 200.
FIG. 11. *Calymperes Levyanum* Besch., from Nicaragua, × 200.
FIG. 12. *Calymperes fluviatile* R. S. Williams, from Porto Rico, × 200.

Contributions to the Mesozoic flora of the Atlantic coastal plain, XIII.—North Carolina*

EDWARD W. BERRY

(WITH TWO TEXT FIGURES)

The Upper Cretaceous deposits of North Carolina were rather fully described in 1912 by Stephenson.† A systematic account of the Upper Cretaceous of the state, its faunas and floras, was planned by the late Wm. Bullock Clark and manuscripts were prepared for the North Carolina Geologic and Econonic Survey, which included an account of the invertebrate faunas by Stephenson, of the vertebrates by Gilmore and of the plants by the present writer. These were transmitted to the State Survey in 1916 for publication and have since been lost. What is known of the fossil flora is contained in a number of short papers published by the writer‡ between 1907 and 1910, and these include nearly everything of interest. It has seemed proper to bring the additional identifications together in the present contribution so that our knowledge of the flora may be complete as regards the present collected material.

The complete flora is arranged botanically in the following pages with brief annotations where such seemed necessary. All of the material comes from what is known as the Black Creek formation.

Thallophyta

ALGITES AMERICANA Berry

Algites americana Berry, Bull. Torrey Club, **38**: 401. 1911; Maryland Geol. Surv. Upper Cretaceous 758. *pl. 50, f. 1.* 1916.

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* The last previous contribution of this series appeared in Bull. Torrey Club **44**: 167–190. *pl. 7.* 1917.

† Stephenson, L. W. North Carolina Geol. and Econ. Surv. **2**: 111–145, 306–314. 1912.

‡ Berry, E. W. Bull. Torrey Club, **34**: 185–206. *pl. 11–16.* 1907; *Ibid.* **35**: 249–260. *pl. 11–16.* 1908; *Ibid.* **37**: 181–200. *pl. 19–24.* 1910; Johns Hopkins Univ. Cir. 11. **7**: 79–91. 1907; Am. Jour. Sci. **25**: 382–386. 1908.

This rather indefinite form is rather common at certain circumscribed localities in the upper part of the Black Creek formation in North Carolina and has also been found in the extension of these beds in South Carolina. It occurs also in the Magothy formation of Maryland.

LOCALITIES: Atlantic Coast Line Bridge, Corbits (Old Union) Bridge, and Horrell Landing, Black River, Sampson County.

Pteridophyta

An undeterminable fern from Court House Bluff, Cape Fear River.

Cycadophyta (?)

CYCADINOCARPUS CIRCULARIS Newberry

PODOZAMITES KNOWLTONI Berry

PODOZAMITES LANCEOLATUS (L. & H.) F. Braun

An extended synonymy of this species was published recently in the Maryland Geological Survey volume on the Upper Cretaceous (p. 772. 1916) and need not be repeated in the present connection. The species is wide ranging both geographically and geologically and is undoubtedly composite. The North Carolina material is fragmentary but cannot be differentiated from the forms universally referred to this species.

LOCALITY: Rockfish Creek near Hope Mills, Cumberland County.

Coniferophyta

TUMION CAROLINIANUM Berry

CEPHALOTAXOSPERMUM CAROLINIANUM Berry

PINUS RARITANENISS Berry

CUNNINGHAMITES ELEGANS (Corda) Endlicher

SEQUOIA MINOR Velenovsky

SEQUOIA HETEROPHYLLA Velenovsky

SEQUOIA REICHENBACHI (Geinitz) Heer

ARAUCARIA BLADENSIS Berry

ARAUCARIA JEFFREYI Berry

ARAUCARIA CLARKI Berry

DAMMARA BOREALIS Heer

BRACHYPHYLLUM MACROCARPUM FORMOSUM Berry

ANDROVETTIA CAROLINENSIS Berry

MORICONIA AMERICANA Berry

Angiospermophyta

ARALES

PISTIA NORDENSKIOLDI (Heer) Berry

Chondrophyllum Nordenskioldi Heer, Fl. Foss. Arct. 3^2 114. *pl. 30, f. 4b; 32, f. 11, 12.* 1874.

Pistia Nordenskioldi Berry, Bull. Torrey Club **37**: 189. *pl. 21, f. 1–15.* 1910.

This species has been fully described and figured by the writer in the publication cited. It is exceedingly common at certain localities and in some cases the cuticle is preserved. The epidermal cells are small, prevailingly rectangular and thick walled. The stomata are few and scattered, confined to a single surface of the leaf and altogether absent from the broad leaf bases. They are situated in depressions of the surface and have thin elongated guard cells and two accessory cells.

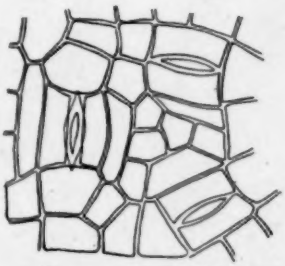

FIG. 1. PISTIA NORDENSKIOLDI (Heer) Berry. Epidermal cell outlines and stomata, × 100.

LOCALITIES: Parker Landing, Tar River, Pitt County; Blackmans Bluff, Neuse River, Wayne County; Sykes Landing (about fifty-seven miles above Wilmington), Corbits Bridge, Big Bend, Atlantic Coast Line Bridge, and Horrell Landing on the Black River, Sampson County.

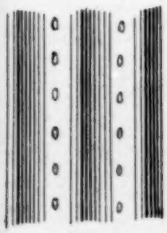

FIG. 2. DORYANTHITES CRETACEA Berry. Longitudinal striations of surface and stomata, × 35.

POALES

PHRAGMITES PRATTI Berry

INCERTAE SEDIS

DORYANTHITES CRETACEA Berry

Doryanthites cretacea Berry, Bull. Torrey Club **38**: 406. 1911; U. S. Dept. Int. Geol. Surv. Professional Paper 84: 108. *pl. 17, f. 3.* 1914; *Ibid.* **112**: 70. *pl. 13, f. 1.* 1919; Maryland Geol. Surv. Upper Cretaceous 806. *pl. 56, f. 6.* 1916.

This species has been sufficiently described in the papers cited, and it remains to refer briefly to the stomata. The longitudinal

veins are immersed and in the valleys are longitudinal rows of small similarly oriented elliptical stomata with pairs of normal guard cells. Both surfaces of the leaf are exactly alike. This species occurs in the Magothy formation of Maryland, the Eutaw formation of Alabama and Tennessee and the Ripley formation of Georgia and Tennessee. In the Black Creek formation of North Carolina it is found at Rockfish Creek near Hope Mills in Cumberland County and at ninety two and ninety-five and one half miles above Newbern on the Neuse River in Wayne County.

MYRICALES

MYRICA ELEGANS Berry

MYRICA CLIFFWOODENSIS Berry

JUGLANDALES

JUGLANS ARCTICA Heer

SALICALES

SALIX FLEXUOSA Newberry

SALIX NEWBERRYANA Hollick

SALIX LESQUEREUXII Berry

SALIX EUTAWENSIS Berry

FAGALES

QUERCUS? PRATTI Berry

This is an extremely doubtful form of slight botanical interest and is probably not a *Quercus*.

QUERCUS PSEUDOWESTFALICA Berry

Quercus pseudowestfalica Berry, U. S. Dept. Int. Geol. Surv. Professional Paper 84: 35. *pl. 9, f. 5.* 1914.

This species, sufficiently described in the paper cited and based upon material from the Middendorf beds of South Carolina, is found in the Black Creek formation of North Carolina at Court House Bluff, Cape Fear River, Bladen County.

URTICALES

PLANERA CRETACEA Berry

FICUS DAPHNOGENOIDES (Heer) Berry

FICUS INAEQUALIS Lesquereux

FICUS STEPHENSONI Berry
FICUS OVATIFOLIA Berry
FICUS CRASSIPES (Heer) Heer

Proteoides crassipes Heer, Fl. Foss. Arct. 3^2: 110. *pl. 31, f. 6–8a.* 1874.

Ficus crassipes Heer, *Ibid.* 6^2: 70. *pl. 17, f. 9a; pl. 24, f. 1, 2.* 1882: Lesquereux, Mon. U. S. Geol. Surv. **17**: 79. *pl. 13, f. 3.* 1892; Berry, Bull. Torrey Club **33**: 172. 1906.

The leaves of this species as they occur in the southern Coastal Plain are narrowly lanceolate with a gradually narrowed apex and base, about 15 cm. in length by 2.5 cm. in greatest width, resembling *Ficus atavina* Heer in outline but relatively narrower. The texture is coriaceous and the midrib and petiole often extraordinarily stout. The secondary venation when seen is of the usual camptodrome type with relatively long ascending secondaries. This species was described originally from the Atane beds of western Greenland, the first rather fragmentary specimens collected having suggested the genus Proteoides. It was subsequently recorded from the Dakota sandstone of Kansas. In the Atlantic Coastal Plain it has been found in the Tuscaloosa, Magothy, Eutaw, Middendorf and Ripley formations. In the Black Creek formation of North Carolina it is found at Court House Bluff, Cape Fear River, Bladen County.

FICUS FRUCTUS

Typical *Ficus* fruits occur at several localities in the Black Creek formation. At Court House Bluff they are associated with at least five foliar species of Ficus. They are about 2.3 cm. in length by 1.1 cm. in maximum diameter. Among previously described forms they are very close to, if not identical with, the figs described by Heer from the Atane beds of Greenland and referred on the basis of association to *Ficus atavina* Heer.* The last is a widespread Upper Cretaceous species which has been found in the Middendorf beds of South Carolina.

LOCALITIES: Court House Bluff and Elizabethtown, Cape Fear River, Bladen County.

* Heer, Fl. Foss. Arct. 3^2 108. *pl. 30, f. 5–7.* 1874.

ARISTOLOCHIALES

Aristolochites Heeri sp. nov.

Leaves of medium or small size, markedly inequilateral in general outline, with a deeply cordate or auriculate inequilateral base and a pointed apex. Margins entire. About 7.5 cm. in length by 4 cm. in maximum width, which is in the basal half of the leaf. Petiole wanting. Midrib stout, prominent, curved. Secondaries stout, diverging from the midrib at wide angles, camptodrome; three or four pairs of reduced caliber diverge fasciculately in the ears from the base of the midrib.

This characteristic species is based upon scanty and fragmentary material. The genus is represented in the Dakota sandstone of the West and in the Arctic Cretaceous, and *Aristolochia*-like fruits and leaves occur from the Eocene onward.

LOCALITY: Court House Bluff, Cape Fear River, Bladen County.

RANALES (?)

DEWALQUEA GROENLANDICA Heer (?)

Dewalquea groenlandica Heer, Fl. Foss. Arct. 6^2: 87. *pl. 29, f. 18, 19; pl. 42, f. 5, 6; pl. 44, f. 11.* 1882.

The North Carolina occurrence is based upon incomplete material collected in 1906, and since no additional material has been discovered I have queried the identification. The question of the correctness of this determination is at best of little significance, either geological or biological. There is some question regarding the generic identity between this species and the type of the genus *Dewalquea* which cannot be settled until better material is discovered, and there is also wide difference of opinion regarding the botanical affinities of *Dewalquea*, some students seeing resemblances to the Ranunculaceae and others to the Araliaceae.

LOCALITY: Blackmans Bluff, Neuse River, Wayne County.

CHENOPODIALES

PISONIA CRETACEA Berry

RANALES

MAGNOLIA CAPELLINII Heer

MAGNOLIA NEWBERRYI Berry
LIRIODENDRON DUBIUM Berry
LIRIODENDRON PRIMAEVUM Newberry (?)
MENISPERMITES CYCLOPHYLLUM Lesquereux (?)

Very typical fragments of some species of *Menispermites* are present in the collections. The material is too incomplete for description but indicates a relatively small form very similar to the Dakota sandstone species *Menispermites cyclophyllum* Lesquereux.* The genus is very common in the earlier part of the Upper Cretaceous in both this country and Europe, as well as in the Arctic region, and continues in the Atlantic Coastal Plain well toward the close of the Cretaceous.

LOCALITY: Court House Bluff, Cape Fear River, Bladen County.

ROSALES

LEGUMINOSITES ROBINIAFOLIA Berry
PHASEOLITES FORMUS Lesquereux
GLEDITSIOPHYLLUM TRIACANTHOIDES Berry

GERANIALES

CITROPHYLLUM ALIGERUM (Lesquereux) Berry

Ficus aligera Lesquereux, Fl. Dak. Group 84. *pl. 10, f. 3–6.* 1892.

Citrophyllum aligerum Berry, Bull. Torrey Club **36**: 258. *pl. 18A, f. 1–8.* 1909; Bull. New Jersey Geol. Surv. **3**: 169. *pl. 21, f. 1–8.* 1911; U. S. Dept. Int. Geol. Surv. Professional Paper 84: 47. 1914.

The occurrence of this species in North Carolina is based upon two fragmentary specimens which are in close agreement with the type but with only a slightly and not conspicuously alate petiole. In this last respect it is exactly like some of the material from the Magothy formation.

LOCALITY: Three and a half miles below Dunbar Bridge, Tar River, Edgecomb County.

* Lesquereux, Cret. & Tert. Flora, 79. *pl. 15, f. 3.* 1883.

EUPHORBIALES

MANIHOTITES GEORGIANA Berry

Manihotites georgiana Berry, Bull. Torrey Club **37**: 507. *f. 1, 2.* 1910; U. S. Dept. Int. Geol. Surv. Professional Paper 84: 114. *f. 2, 3; pl. 22; 23, 24, f. 4, 5.* 1914.

This remarkable species has been fully described in the publications cited. It is found in the Eutaw formation in Georgia and Tennessee, in the Ripley formation of Georgia and Tennessee and in the upper part of the Bingen sand in Arkansas.

LOCALITY: Neuse River, eighty-seven and a half miles above Newbern, Wayne County.

SAPINDALES

CELASTROPHYLLUM CRENATUM Heer

CELASTROPHYLLUM UNDULATUM Newberry

MALVALES

PTEROSPERMITES CAROLINENSIS Berry

PTEROSPERMITES CREDNERAFOLIA Berry

THYMELEALES

CINNAMOMUM HEERII Lesquereux

MALAPOENNA HORRELLENSIS Berry

LAUROPHYLLUM ELEGANS Hollick

SASSAFRAS ACUTILOBUM Lesquereux

Sassafras acutilobum Lesquereux, Cret. Flora, 79. *pl. 14, f. 1, 2.* 1874.

This species is apparently widely distributed and almost as variable as the modern *Sassafras*.

LOCALITY: Court House Bluff, Cape Fear River, Bladen County.

MYRTALES

EUCALYPTUS ATTENUATA Newberry

EUCALYPTUS LINEARIFOLIA Berry

EUCALYPTUS GEINITZI Heer

The foregoing three species are believed to represent *Myrcia* or some similar genus of the Myrtaceae. They are not considered

to represent *Eucalyptus* and should probably be referred to the form-genus *Myrtophhyllum*.

UMBELLALES

CORNOPHYLLUM OBTUSATUM Berry

Cornophyllum obtusatum Berry, U. S. Dept Int. Geol. Surv. Professional Paper 112: 129. *pl. 26, f. 7, 8.* 1919.

This species is sufficiently described in the publication cited and was based upon material from the Tuscaloosa formation of Alabama.

LOCALITY: Court House Bluff, Cape Fear River, Bladen County.

HEDERA PRIMORDIALIS SAPORTA

ERICALES

ANDROMEDA PARLATORII Heer

ANDROMEDA GRANDIFOLIA Berry

ANDROMEDA NOVAECAESAREAE Hollick

KALMIA BRITTONIANA Hollick (?)

PRIMULALES

MYRSINE BOREALIS Heer

MYRSINE GAUDINI (Lesquereux) Berry

EBENALES

DIOSPYROS PRIMAEVA Heer

GENTIANALES

ACERATES AMBOYENSE Berry

INCERTAE SEDIS

Carpolithus carolinensis sp. nov.

A symmetrically ovate, ligneous, biloculate, compressed capsule, pointed at both ends, about 10 mm. in length and 7 mm. in maximum width, midway between the apex and the base.

Of unknown botanical affinity.

LOCALITY: Big Bend, Black River, Sampson County.

Carpolithus bladenensis sp. nov.

A smooth hard nutlet, drupaceous stone or seed, almost perfectly elliptical in outline when viewed from either the front, side or end. Length 11 mm., width 5 mm., thickness 2.3 mm.

Species obviously distinct, based upon a single specimen from the dark clays of the Black River. In form it suggests such modern stones as those of *Cornus florida* or *Nyssa biflora* but the dark polished surface is perfectly symmetrical. Botanical affinity unknown.

LOCALITY: Atlantic Coast Line Bridge, Black River, Sampson County.

The silicious skeleton of tracheids and fibers*

FOREST B. H. BROWN

(WITH FIVE TEXT FIGURES)

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I. INTRODUCTION AND DISCUSSION OF PROBLEM

It is a remarkable fact that when the water-saturated secondary xylem of the stem is allowed to dry, it shrinks considerably in both radial and tangential diameters but only slightly in length. Conversely, when the dry secondary xylem imbibes water it swells mainly in its radial and tangential dimensions but remains nearly constant in length. The swelling and shrinking of the xylem, therefore, takes place mainly at right angles to the axis of growth. Relative stability of length during the imbibition or evaporation of water is a strongly marked physical property of the xylem in either the living or dead tissues of all woody plants; and the bast, in all cases examined by the writer, has been found to exhibit essentially the same properties of swelling and shrinking as the xylem.

The amount of swelling of the xylem of a large number of species has previously been determined by careful measurements without, however, arriving at a satisfactory explanation of the phenomena observed. The details of anatomy of these tissues have not hitherto made it apparent why one dimension should

* Contribution from the Osborn Botanical Laboratory.

vary independently of another. Nothing in the relative size, shape, or arrangement of the cells would bring about a result of this kind.

In a strand of bast, for example, it is difficult to conceive of any change in the dimensions of the tissue as a whole which would not involve a corresponding change in the dimensions of each component fiber, and this statement would apply equally to the xylem. Hence it is apparent that the basis for an explanation of the phenomena of swelling and shrinking in these mechanical tissues must, in its last analysis, lie, not in the structure of the tissue as composed of cells, but in the structure of the membrane as a part of the cell.

During the years 1917–1920, the writer devoted a portion of the time to a study of the minute structure of the thickened membranes which characterize the mechanical tissues of the stem, and in the course of this work the probable explanation of the phenomena just described became apparent. It was found that longitudinal tracts in the secondary thickening of the wall in the fibers and tracheids of the wood and in the fibers of the bast are more highly mineralized than the material of which the rest of the wall is composed. These mineralized tracts or rods, in which silicious material appears always to be present, run longitudinally from one end of the fiber to the other and constitute a skeleton-like structure (see FIG. 3) which, there is every reason to believe, must have a direct effect upon the physical and mechanical properties of the fiber or tracheid in the walls of which it is imbedded. In contrast to the other parts of the wall substance, these silicious rods imbibe little or no water and hence would neither swell nor shrink with such variation in the amount of imbibition water as may take place in the hygroscopic colloidal material in which they are imbedded, as in a matrix. The matrix, on the other hand, absorbs water freely, so that the dry lignified walls, according to Pfeffer,* may take up as much as 51 per cent of their weight in water. Presumably the colloidal material tends to swell equally in its different axes during imbibition; but the mechanics of movement permitted by the silicious skeleton in relation

* Pfeffer, W. The physiology of plants. English translation. Oxford. Vol. 1, p. 209.

to the colloidal matrix is, to all appearance, such as would almost inhibit any tendency of the fiber or tracheid to swell or shrink longitudinally. Since, however, the rods of the skeleton are not generally connected laterally and would therefore be free to move apart or approach more closely to one another, they would allow the matrix in the spaces between to swell or shrink along any of the transverse diameters of the fibers.

These details in the structure of the cell-wall make it clear that the shrinking or swelling of the xylem or bast would not materially change the longitudinal dimensions of these tissues. Hence the fiber-walls of living tissues, as soon as the silicious skeletons are formed, may function in the diffusion and transport of liquid solutions or may swell or shrink in diameter with the increase or decrease of imbibition water, with the fluctuations of turgor in the cells, or with the changes of sap pressure in the conducting elements; at the same time they may offer the undiminished resistance to longitudinal tension or compression necessary for the mechanical support of the stem. Except for decay, the changes which take place with the death of the cell—in the haulms of rye and other grasses after the ripening of the seed or in the xylem of the tree after one or more years—do not materially affect the structural or physical properties of these tissues.

The writer is indebted to Professors A. W. Evans, G. E. Nichols, and other members of the Department of Botany for material and for many valued suggestions and criticisms throughout the investigation; to Professor H. N. Whitford and other members of the School of Forestry for material of *Tecoma* and other woody plants; and to Professors A. J. Hill of the Department of Chemistry and W. E. Ford of the Department of Mineralogy, to whom portions of the work have been submitted for criticism.

II. HISTOLOGICAL ELEMENTS OF TRACHEIDS AND FIBERS

In the course of the investigation the secondary xylem and, in some cases, the bast of approximately five hundred species were examined by the writer, with the result that the structure of the fiber wall in all was found to be essentially the same. Of

the various species examined, the wood fibers of lapachol-forming* species of *Tecoma* seem as favorable as any for the observation of those details with which this paper is chiefly concerned, and all references to this genus have special application to those species in the vessels of which the sulphur-yellow, monoclynic crystals of lapachol are found.

1. MIDDLE LAMELLA AND PRIMARY THICKENING

In an unstained cross-section of the xylem of *Tecoma* mounted in glycerine, it is observed that the middle lamella and primary thickening of the fiber (FIG. 1, *A*) are highly refractive and not

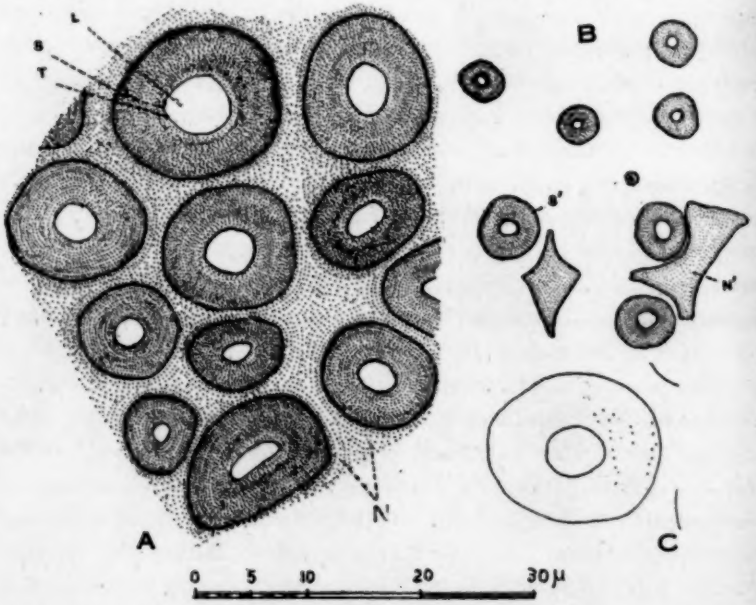

FIG. 1. *A* and *B*, cross-section of xylem of *Tecoma* sp. *A*, before treatment; *B*, after desilicification and drying—*L*, lumen; *S*, secondary thickening; *T*, tertiary thickening; *N*, middle lamella and primary thickening. *C*, secondary thickening of a single tracheid, showing a number of skeleton rods.

* Lapachol is a natural quinone dye, which is found in vessels of the heart-wood of several species of *Tecoma*, natives mainly of South America. It forms a sulphur-yellow dust over the cut surface of the wood and, when moistened by ammonia or dilute sodium carbonate, turns deep wine-red, serving as a reliable character in the identification of the wood. Also, fine chips of the wood, upon standing in a test tube partly filled with dilute aqueous solution of sodium carbonate, will turn the liquid a deepred color.

easily differentiated from each other. In the xylem of *Tecoma* and many other genera, these two membranes differ little from one another in appearance. They stain nearly alike, have nearly the same index of refraction, and are similar in chemical and physical composition, so that, without special technique, they are indistinguishable from one another (as shown in *N*, FIG. 1). They may be differentiated, however, in certain refractive media, as shown by the writer in an earlier paper;* or, better, by mounting cross-sections 10–20 μ thick in dilute Shultze's solution, warming the slide slightly, and observing under high power. In Schultze's solution the true middle lamella is dissovled before the primary thickening of the fiber. These two membranes together compose about one half of the cross-section area, and, when treated with phloroglucinol and hydrochloric acid, give the deep red reaction for furfurol. It is also a noteworthy fact that the index of refraction of these layers, which is about 1.59 (that of the middle lamella being slightly higher than that of the primary thickening), approaches the refractive index of the calcified wall of the calcareous alga *Penicillus* (n = 1.60). *Tecoma* forms an unusually good subject for study because there are few genera in which the primary thickening is as well developed as in this genus. In many genera, even those in which the secondary layer is well developed, as in *Quercus*, *Caesarea*, or *Aspidosperma*, the primary thickening is extremely thin and may even appear to be absent.

2. SECONDARY AND TERTIARY THICKENINGS

The secondary thickening (*S*, FIG. 1) is well developed in all the lapachol-yielding species of *Tecoma*, and appears more or less rounded or even circular in outline in the transverse section. The index of refraction of this thickening of the fiber is slightly below that of quartz, the refractive index of which is 1.54. A thin highly refractive tertiary layer (*T*) borders the lumen (*L*). Neither of these thickenings reacts for furfurol, and both are therefore unlignified in all the lapachol species of *Tecoma* examined. In other genera the thickening is commonly lignified.

When cross-sections are first mounted in glycerine or water, the secondary layer appears to be of homogeneous composition;

* Brown, F. B. H. The refraction of light in plant tissues. Bull. Torrey Club 47: 243–260. *f.* 1–4. 1920.

but, upon standing a few hours, small isolated areas (FIG. 1, *C*) may be distinguished. These areas appear to be slightly more refractive than the material of which the rest of the secondary thickening is composed, when the wall has taken up as much as it will of the liquid in which it is mounted. They are circular in outline, 1–3 μ in diameter, approximately two hundred in number in the cylindrical portion of the fiber, and distributed quite evenly through the secondary thickening of the wall. They are without order of arrangement except that those of larger diameter appear to be placed near the outside. The exact size and position in the fiber wall of areas seen with sufficient clearness to be drawn with the Abbé camera are shown in FIG. 1, *C;* numerous others could be seen distributed evenly through this membrane but not with sufficient clearness to be projected.

One effect of imbibition upon the membrane-mass would be to lower the index of refraction of that portion which takes up the liquid. From the fact that the relatively more refractive areas appear in the membrane after the imbibition of water or glycerine, it is indicated that these portions of the membrane imbibe little or no liquid; the remainder of the membrane, on the other hand, is evidently composed of hygroscopic material. The impermeable areas, in all probability, represent the cut ends of silicious rods which, as will be shown presently, form a skeleton-like structure in the secondary thickening of the fiber.

3. HISTOLOGICAL ELEMENTS OF THE SECONDARY THICKENING

The secondary thickening of fibers of the xylem of *Quercus, Hicoria, Caesarea, Aspidosperma,* and the majority of woody plants forms nearly the entire cell-wall. It is without doubt essential to the mechanical strength of these sclerous membranes and is never absent in fibers the longitudinal dimensions of which tend to remain unchanged under different conditions of moisture.

As previously mentioned, small isolated portions of this thickening of the fiber in *Tecoma* are composed of non-hygroscopic material. If the untreated section is placed upon a mica slip and held over an alcohol flame until the fibers are partly burned to ash, numerous hyaline, non-combustible, rods of mineral composition are left partly free along the burned margin of the secon-

dary layer, held in position by what remains of the charred matrix (FIG. 2, *A*). In all probability the cut ends of these mineralized rods are identical with the small non-hygroscopic areas which were observed in the untreated membrane after being mounted for some time in water or glycerine. The material of which these tracts in the wall are composed is therefore non-hygroscopic as well as non-combustible. The solubility of the rods so isolated was tested in various reagents; but such results can have little significance as to the original composition, since the chemical composition, as well as the refractive properties of the rods, was found to undergo great change during the process of burning. In some cases, the rods became covered with a thin film of black material highly resistant to nitric, sulphuric, hydrochloric and even hydrofluoric acid.

As will be shown presently, these rods are composed, in part at least, of silicious material and form a skeleton-like structure in the secondary thickening of the fiber wall. The remainder of the secondary thickening (in which the rods are imbedded) may be termed the colloidal matrix, for reasons which will be given more fully later.

The histology of the secondary thickening of the fibers or tracheids in the wood and of the fibers of the bast in all species examined by the writer is essentially the same as that observed in the xylem of *Tecoma*. It is composed of the following two structural elements, which differ from each other in their physical and mechanical properties as well as in their chemical composition: namely, (1) a non-hygroscopic silicious skeleton imbedded in (2) a hygroscopic colloidal matrix. With little doubt,

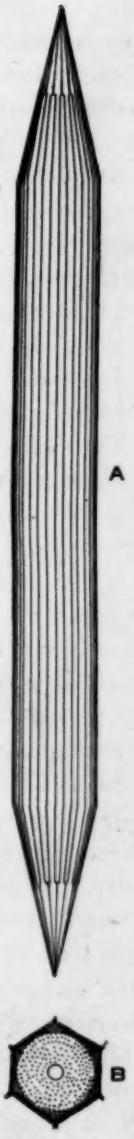

FIG. 2. Silicious skeleton, diagrammatic. *A*. longitudinal view; *B*, transverse view, the shaded portion representing middle lamella and primary thickening.

these structures are independent of each other in the properties which they impart to the wood. They may therefore be separately considered.

a. Silicious skeleton

Structure.—The longitudinal rods, of which the silicious skeleton of tracheids and fibers is composed, are nearly straight, parallel, and extend longitudinally in the colloidal matrix from one end of the tracheid or fiber to the other.

The number of vertical rods in a skeleton varies according to the genus or species, from possibly as few as four in the tracheids of *Trochodendron* to possibly as many as two hundred in the fibers of *Tecoma*.

These rods occasionally branch or coalesce—more frequently in some species than in others. The coalescence probably serves to reduce the number of vertical rods in the tapering ends of a fiber or tracheid, as shown diagrammatically in FIG. 2; in conifers the rods branch around the large circular pits or become reticulate where the pits are numerous; in *Pinus Strobus*, a silicious ring encloses the extreme border of each large pit. Scalariform pitting in particular makes necessary a great reduction in the number of vertical rods in a tracheid. Thus in *Trochodendron* a single rod of comparatively large diameter passes to each side of a vertical series of the transversely elongated pits and a transverse rod of smaller diameter passes between each two pits of the series and joins at either end to each of the vertical rods like the rounds of a ladder. Hence, judging from the structure of the skeleton, the pits and pit-areas would not swell or shrink in either the longitudinal or the transverse planes. The rods are filamentous in shape and are, as before mentioned, probably less than 3 μ in diameter. The details of structure, as summarized above, may be observed in burned preparations, as follows: from small transverse sections of the xylem of *Tecoma* 15–20 μ thick, it is found that as many as twenty rods may be seen partly exposed along the burned outer margin of the secondary layer (FIG. 3, *A*). On burning deeper inward toward the center of the fiber, other rods would undoubtedly be exposed; hence it may be assumed that not less than a hundred rods may be present in the fiber, of which only twenty are exposed at the margin. In unburned

sections mounted in glycerine, the number of rods as estimated from the refractive areas was placed at about two hundred. The difference in estimates from burned and unburned material

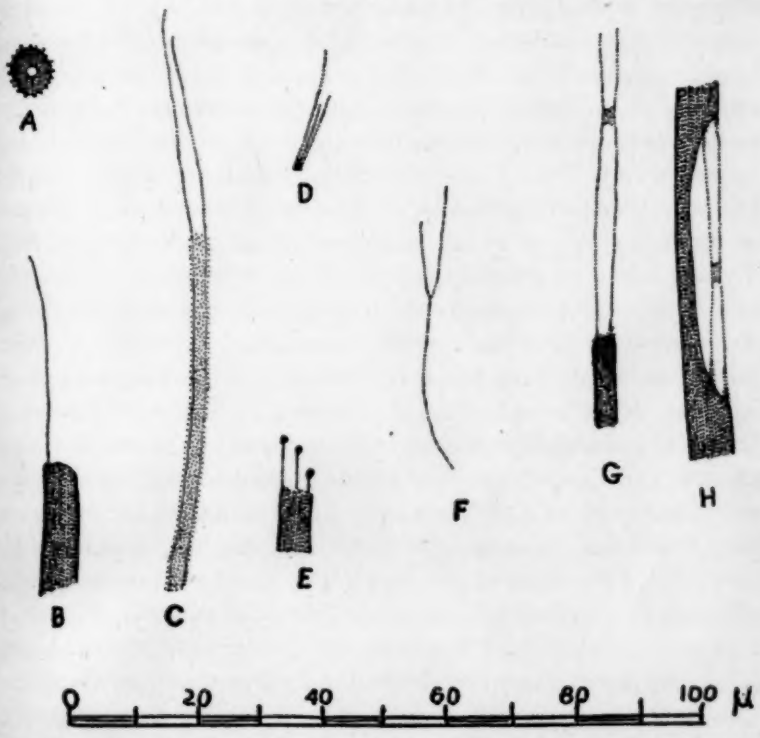

FIG. 3. Burned material. *A*, cross-section of fiber showing exposed skeleton rods; *B, C, D, G, H*, showing unbranched rods; *G* and *H*, showing lateral ties; *F*. branched rod; *E*, glass beads formed by heat.

may be explained from the probability that part of the rods in the burned material may have been broken off close to the matrix and therefore were not seen. The number of rods in a fiber of *Tecoma* may therefore be estimated at not less than one hundred and possibly twice that number.

The relative position of the rods in a fiber and the mnaner of branching may be observed from burned macerated material. When the wood of *Tecoma* is treated with Schultze's solution, using 50 per cent nitric acid, it is possible to dissolve away both the middle lamella and primary wall of the fiber. The tertiary

layer in most of the fibers is thin and poorly defined, hence what remains of the fiber wall after thorough maceration is composed almost wholly of secondary thickening. When these macerated fibers are washed, dried, then burned on a mica slip, the isolated or partly isolated rods, and their relative position and branching may be observed. In *B*, FIG. 3, is seen an isolated unbranched rod over 30 μ in length, projecting from the charred end of a partly burned fiber; in *D* are shown three such rods. Two parallel unbranched rods (FIG. 3, *C*) were traced a distance of 90 μ, partly free and partly imbedded in a transparent matrix of unburned material, as shown in the drawing. In burned tracheids of *Trochodendron*, unbranched rods 1.15 mm. in length were found in one instance. Occasionally the rods branch as shown in *F*, from *Tecoma*. The diameter cannot be accurately determined from burned material, since products of combustion and fusion adhere as a film to the outer surface of the rods. It is probable that the lateral ties observed between neighboring rods, as shown in *G* and *H*, FIG. 3, are merely the products of combustion and hence not a structural feature of the skeleton. From such data the structure of the skeleton, as well as its position in the fiber wall, may be inferred. The essential feature of the skeleton consists in the presence of longitudinal rods, and these were never found absent from the fibers and tracheids of the wood or in the fibers of the bast in any species examined by the writer. Other details of the skeleton, however, may vary considerably, according to the species, genus, or family in which it occurs. Thus, in the thin-walled fibers of *Ochroma lagopus*, the rods are few in number; in the thick-walled fibers of *Tecoma*, *Aspidosperma*, *Caesarea*, *Cedrela*, *Swietenia* and *Hicoria*, they are numerous; in *Guaiacum*, they are numerous and of extremely small diameter; in *Pinus Strobus*, they are relatively much branched; in *Araucaria brasiliana*, they are few and of unequal diameter. Silicious rods are present in the fibrous strands in the haulms of *Secale cereale*, but in the walls of the epidermis the silica is distributed more uniformly, so that, after burning, the cellular structure including the guard cells of the stomata is preserved.

Chemical composition.—The skeleton-rods in all species examined were found to be composed, in large part at least, of non-

combustible material. That the chemical composition varies in different species is certain, but silica or some silicate is evidently present in very case. That the skeleton-rods of *Tecoma* are highly silicified is plainly shown from an examination of burned macerated fibers before and after treatment with hydrochloric, nitric, and hydrofluoric acid. Before treatment with acid the rods are invariably present; also, after treatment with hydrochloric or nitric acid they are present; but after treatment with hydrofluoric acid they are invariably absent.

Furthermore, it is of great interest to note that the heat generated by an alcohol flame, together with that of the burning fiber, is sufficient to cause the formation of glass beads, usually at the ends of the silicious rods, as shown in FIG. 3, *E*. This often happens when the calcium-rich fibers of *Tecoma* are burned and less frequently in calcium-poor material like *Secale*. These beads are insoluble in hydrochloric, nitric, or sulphuric acid and have an index of refraction of 1.59, approaching that of flint glass. The calcium is, in all probability, changed to lime by the heat, and would thus act as a flux upon any silica in the rods, causing the formation of the highly refractive glass beads. The result would be the same whether the rods were composed of silica, such as quartz or opal, or of highly silicified material. Also, the same reaction to hydrofluoric acid would be obtained in either case, since either silica or silicates would be quickly dissolved by this reagent.

The question now arises whether the silica in the secondary thickening of the *Tecoma* fiber is actually present in an amount that would be necessary, if it is assumed that the skeleton rods are composed either of silica or of highly silicified material. Macerated material may be used in an approximate anaylsis of the mineral content of this portion of the fiber wall, since in the species of *Tecoma* examined the vessels, ray cells, and elements other than the fibers have thin walls and do not make up a material part of a macerated preparation. It was thus possible to obtain several grams of material made up in large part of the secondary thickening of fibers; after combustion, 1.8 per cent (of the dry weight of the fiber) of mineral matter was obtained and .1 per cent (of the dry weight of the fiber) of silica or silicic acid. Silicon

is therefore not abundant in the secondary thickening of the fiber of *Tecoma*, but if concentrated in the skeleton rods the amount would be more than sufficient to form a skeleton with two hundred vertical rods composed either of silica or of some highly silicified material.

Various evidences make it almost certain that the composition of the rods varies in different families, genera, and species, though silica or silicious matter may always be present. This is indicated in the fact that the effect of hydrofluoric acid upon the mechanical rigidity of the fiber is quite different in some species from what it is in others. Thus in *Tecoma* and several other genera, as will be described more fully presently, the fibrous tissues of the xylem suddenly contract more than 20 per cent in length during treatment with hydrofluoric acid; the wood of *Aspidosperma* and of numerous other genera, on the other hand, is merely softened by this treatment. Also, hydrochloric acid attacks the skeleton rods of *Guaiacum* sp. and softens the wood sufficiently to permisectioning in the microtome; but with this acid there is no material contraction of the fibers, and the skeleton rods are still present in the ash, though a large portion of the outer mineralized film has apparently been dissolved by the acid. In this case the rods may be composed of a central axis of silica or of highly silicified material, enclosed by a thin outer covering of mineral composition which is partly soluble in hydrochloric acid.

That the skeleton rods are not composed entirely of crystalline silica is evident from the fact that when the macerated fibers of *Tecoma*, *Aspidosperma*, *Secale* and all the other genera examined are mounted in strong sulphuric acid, the entire wall is dissolved without leaving any insolubl eremains which might be positively identified as part of a skeleton rod. But the rods seem to be more slowly disintegrated than the matrix, and hence they not infrequently remain visible a short time in the acid after the rest of the wall has been dissolved. The evidences as a whole therefore favor the conclusion that the skeleton rods are composed of highly silicified material, the composition of which varies in the different families, genera, and species.

Physical properties.—As before mentioned, the rods probably imbibe little or no liquid and hence under ordinary temperature

conditions would tend to remain of constant length, though the water content of the matrix might vary considerably. With the application of force, however, the rods would shorten or lengthen within the elastic limits of the material of which they are composed. Under high temperatures the rods appear to undergochange in composition, possibly giving off moisture, and may then be observed to contract in length.

b. Colloidal matrix

The material in which the skeleton rods are imbedded exhibits essentially the properties of matter in the colloidal state. Besides being highly hygroscopic and gelatin-like in many of its microscopic characters, it has the property of imbibing methylene blue and other colloidal solutions even in the living condition. The term colloidal matrix is therefore used to designate that portion of the secondary thickening of fibers and tracheids in which the silicious skeleton is imbedded; it is apparently stretched upon the silicious skeleton under longitudinal tension strain. This is indicated from the fact that after a macerated fiber of *Tecoma* (*A*, FIG. 4) has remained a few minutes in hydrofluoric acid, it suddenly contracts 36 per cent or more longitudinally, and, at the same time, increases often as much as 100 per cent in diameter, as shown in *B*, FIG. 4,

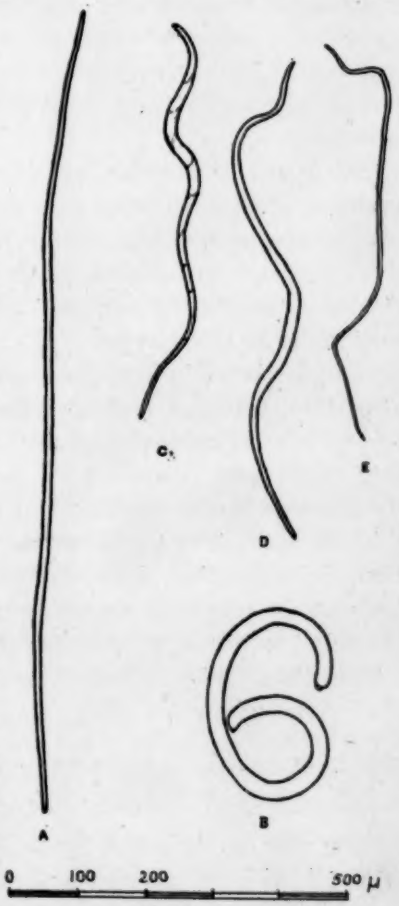

FIG. 4. Isolated fibers of *Tecoma*. *A*, before treatment; *B*, same fiber after desilicification; *C*, *D*, typical desilicified fibers; *C*, showing spirals; *E*, same as *D* after drying.

which is an accurate drawing of *A* after desilicification. Usually the contracting fibers increase much more in diameter toward the center than near the ends, as has been accurately shown in *C* and *D*. In any case the secondary thickening of the fibers contracts in length and expands in diameter with an elastic force sufficient to separate this thickening from the primary thickening, and to burst the mdidle lamella, medullary rays and other parts of the woody tissue sufficiently to allow the transverse expansion.

After the dissolution of the silicious skeleton the colloid matrix is gelatin-like in texture, without mechanical rigidity, and assumes various curved outlines as shown in *B*, *C*, and *D*. It absorbs water freely, and, when dried, shrinks greatly in both diameter and length as shown in *E*, FIG. 4, which is an accurate drawing of *D* after drying. The contraction in diameter is more accurately shown in FIG. 1, *B*, which represents the remains of *A* after desilicification and drying. The primary thickening and middle lamella (*n*) are broken into fragments but shrink comparatively little (*n'*).

The structure of the colloidal matrix may be observed in desilicified fibers mounted in water. Owing to differences in refraction, delicate spiral lines of material may be observed in the body of the matrix as shown in FIG. 4, *C*. Further evidence of the spiral structure of the colloidal matrix is found in the inclination of the slit-like orifices of the fiber pits, which coincides with that of the spirals.

III. INHIBITING EFFECT OF SKELETON UPON THE SWELLING OF THE MATRIX

Since the non-hygroscopic skeleton rods would remain constant in length with the varying moisture content of the matrix, they would inhibit any tendency of the matrix to swell or shrink longitudinally, except in so far as would be permitted by their elasticity. With the application of force, a certain amount of longitudinal compression or stretching of the skeleton rods would undoubtedly be permitted; hence the slight longitudinal swelling and shrinking of woody tissues, which at most amounts to only 1 to 2 per cent, may take place by reason of the elastic property of the rods.

Any tendency of the matrix to shrink or swell along the diameter of the fiber, would not be inhibited by the unbranched vertical rods, since these would move apart or approach with the swelling or shrinking of the matrix. As previously explained, the branching of the skeleton in pit areas would indicate that these areas of the wall swell or shrink only in thickness if at all.

IV. EFFECT OF DESILICIFICATION UPON THE MECHANICAL RIGIDITY OF THE TISSUES

That the silicious skeleton is of fundamental importance to the mechanical rigidity of the tissues is indicated by the effect of desilicification. The haulms of *Secale*, for example, when placed in hydrofluoric acid, contract with elastic force over 30 per cent in length and at the same time expand approximately 100 per cent in diameter. The desilicified tissues have a rubber-like elasticity and may be stretched nearly to the original length.

Remarkably similar effects are obtained when the xylem of *Tecoma* is desilicified. In the accompanying table (TABLE I), the length of a block of wood and the radial and tangential dimension are recorded at indicated intervals during treatment; the gain or loss relative to the respective dimensions of the tissue in the dry state are incased in parentheses.

The rate and relative amount of swelling or contraction in length and in the radial and tangential dimensions of the block, the measurements of which are given in the table during the period of treatment are shown in the graph, FIG. 5. During the five and one half hours in boiling water (*A* to *B*), the tissues swelled barely 1 per cent in length, though both diameters increased more than 10 per cent. At length, all dimensions became stable in water and changed but slightly if at all during the first seventeen hours (*B* to *B'*), when the water-saturated wood was transferred to strong hydrofluoric acid.

Up to time *B'*, only the usual phenomena of swelling in woody tissues are recorded, of which the relative constancy of length is the remarkable but characteristic feature. At *B'*, however, changes of an essentially different character began; the length, which up to this time had remained almost constant, now rapidly contracted over 20 per cent, while the radial and tangential diameters expanded over 40 and over 50 per cent, respectively.

TABLE I

CHANGES IN LENGTH AND DIAMETERS OF XYLEM OF *Tecoma* UNDER DIFFERENT CONDITIONS.

In parentheses is indicated the per cent of gain or loss, relative to dimensions in the dry state.

Length		Radial diameter		Tangential diameter		Hours	Conditions
5.52 mm.		8.53 mm.		8.47 mm.		10.	In air, 100° C.
5.52 "		9.07 "	(+6)	9.09 "	(+7)	10.5	In water, 100° C.
5.53 "	(+0.1)	9.40 "	(+10)	9.50 "	(+11)	11.0	" " "
5.53 "	"	9.48 "	(+11)	9.55 "	(+12.7)	11.5	" " "
5.53 "	"	9.48 "	"	9.55 "	"	13.0	" " "
5.53 "	"	9.48 "	"	9.60 "	(+13.)	15.0	In HF
5.53 "	"	9.48 "	"	9.80 "	(+15.)	19.0	" "
5.53 "	"	9.48 "	"	9.80 "	"	22.0	" "
5.53 "	"	9.48 "	"	9.80 "	"	32.0	" "
4.7 "	(−14.8)	11.3 "	(+32)	14.22 "	(+67.8)	33.5	" "
4.5 "	(−18.0)	12.2 "	(+43)	15.7 "	(+85)	35.0	" "
4.4 "	(−20.3)	11.0 "	(+29)	14.5 "	(+71)	38.0	" "
4.3 "	(−22.0)	11.0 "	"	13.3 "	(+57)	43.0	" "
4.3 "	"	11.0 "	"	13.3 "	"	48.0	" water
4.3 "	"	11.0 "	"	13.3 "	"	56.0	" "
3.3 "	(−40.0)	6.9 "	(−19)	7.3 "	(−13.8)	56.5	" air, 100° C.
3.3 "	"	6.9 "	"	7.3 "	"	6.4	" " "

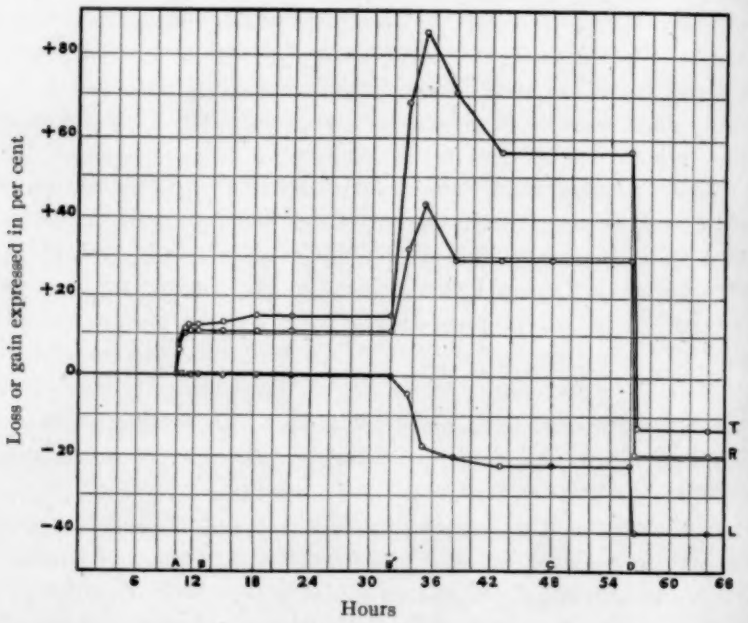

FIG. 5. Graph showing changes in the different dimensions of the xylem of *Tecoma* during treatment; *A*—*B*, in boiling water; *B*—*C*, in hydrofluoric acid. A collapse of mechanical rigidity commences at time, *B'*, *C*—D. in running water; *D*, in air, 100° C.

The transverse dimensions subsequently contracted to some extent, but after a few hours all dimensions remained nearly constant, whether left in acid, or transferred to water (*C* to *D*). The subsequent great contraction (*D*) of all dimensions which took place when the desilicified tissues were dried, indicates the almost complete loss of mechanical rigidity of the xylem after desilicification.

The changes which occur in the longitudinal dimensions of a block of the xylem of *Tecoma* during treatment are essentially the same as those which occur in the isolated fiber under the same treatment. Probably up to time *B'* the skeleton rods had not been weakened by the acid. But immediately after *B'* there was a rapid contraction in length and expansion in the transverse dimensions, such as would occur with the collapse of the skeletons; the entire course of the curves during the first part of the time, *B' C*, indicate the collapse of the mechanical element of the xylem.

A similar amount of longitudinal contraction and transverse expansion occurred in the xylem of all of the thirty lapachol-yielding samples of *Tecoma* examined. Similar changes were observed in approximately one-fifth of the species of the other genera and families examined by the writer; but the amount varied with the genus and species. Many species such as *Aspidospermas*, showed little or no longitudinal contraction during desilicification. Such differences in the effect of desilicification are reasonably explained on the assumption that the rods must differ in chemical composition, according to the species, although silicious material may be present in each case.

V. SUMMARY

The longitudinal dimensions of the xylem and bast in either living or dead tissues are subject to little variation upon soaking in water or drying, by reason of a silicious skeleton in the secondary thickening of the fibers and tracheids. This skeleton is composed of sparingly branched non-hygroscopic rods of silicified material which extend longitudinally in the hygroscopic cell-membrane from one end of the fiber or tracheid to the other

Except for local areas, the longitudinal skeleton rods are not branched or united in a way to prevent them from being spread

apart or crowded together; hence the swelling and shrinking of the cell-wall may take place at right angles to the axis of growth.

In the vicinity of pits, such as the circular pits of *Pinus Strobus* or the scalariform pits of *Trachodendron*, the vertical system of rods is replaced by reticulate branches or transverse connections which would probably inhibit swelling or shrinking of these areas in all directions except, possibly, in thickness.

The skeleton rods are composed of highly mineralized material, the composition of which varies in the different families, genera, and species; but silica or some silicate is present in at least a large number of cases.

The effect of zinc sulphate on protoplasmic streaming

HESTER M. RUSK

(WITH TWO TEXT FIGURES)

In view of the fact that metallic poisons in minimal doses stimulate the metabolic activity of many plants, as has been shown by the researches of many workers, it seemed a matter of interest to determine whether any ocular evidence of excitation could be observed in individual cells. Of all the poisons employed we have the most data regarding the effect of zinc sulphate, and in this work the observations were limited almost entirely to the action of that salt. A few observations were made with other substances, such as cobalt nitrate and sulphuric acid, but without very definite results. The most convenient visible reaction to observe is the effect on the rotation of protoplasm in active cells. For this purpose cells of the leaf of *Elodea canadensis* and cells from an uncorticated *Chara* were taken.

While the literature is rich regarding the action of metallic poisons on the stimulation of growth and certain of the metabolic processes concerned in the use of nutrient material, there is not a large amount on the effect of irritant substances on the rate of streaming. Ewart (**1**, p. 87) says, "all concentrations [of metallic poisons] sufficient to produce any effect cause from the outset progressive retardation." He cites only experiments with sodium chloride (0.1–0.5 per cent) and cupric sulphate (0.5–10 per cent), however.

With regard to the effect of metallic poisons on other functions of plants it has been found (1) That zinc sulphate in concentrations from 0.000125 *N* to 0.002 *N* stimulates the growth of *Aspergillus niger* and *Penicillium glaucum*, resulting in an increase of dry weight. The greatest stimulation was obtained by a concentration of from 0.000125 *N* to 0.0005 *N* (see Richards, **2**). (2). That the same concentrations of zinc sulphate stimulate the same fungi, causing them to make a more economical use of sugar. The greatest stimulation was obtained by 0.00025 *N* (see Richards, **3**). (3) That zinc sulphate in concentrations from

0.0003 *N* to 0.0015 *N* stimulates *Sterigmatocystis nigra* with the result that less nitrogen is fixed by the fungus. The greatest stimulation was obtained by solutions from 0.0003 *N* to 0.001 *N* (see Latham, **4**).

For the test solutions in this work Merck's reagent zinc sulphate was used and was kept sealed with paraffin when not in use. It was weighed out on a delicate Becker balance, and a 0.1 *N* stock solution made. For most of the work with *Elodea*, the stock solution was made up in distilled water; but for part of this work, and for all of that with *Chara*, double distilled water was used. Dilutions were made from this stock solution as needed. For all measurements accurately graduated flasks and pipettes were used. Filtered tap water was considered to be a better medium for controls than distilled water, since it is much more like the medium in which these plants naturally live. Hence tap water, filtered through a Berkefeld filter, was used for controls; it was also used for making dilutions from the stock solution of sinc zulphate, so as to make the test solutions differ from the control only in the presence of the zinc sulphate.

A stock supply of the plants was kept in the greenhouse in jars with snails. Small amounts were brought into the laboratory from time to time, and kept in filtered water. Specimens put into test solutions were taken directly from filtered water. The temperature of the water or solution was between 19° and 25° C. at the beginning of all the observations; at the beginning of all but a very few it was between 21° and 24° C. The light used for all the observations was that of a 60-watt lamp coming to the mirror of the microscope through an ammonia copper sulphate globe.

For most of the work with *Elodea* the following method was used: Several healthy looking leaves were taken from the same region of the same stem, and placed, some in a separate dish of filtered water, and some in a similar dish containing about an equal amount of the zinc sulphate solution. One of the leaves from the zinc sulphate solution was then mounted on a slide in some of the same solution, and observations were made on from three to five of its cells. This was done within an hour and a half of the time of starting. Then a leaf from the dish of filtered

water was mounted and observed similarly. This whole proceeding was carried on within two hours and a half.

For the last part of the work with *Elodea*, the method was changed in the following way. The control observations were made first. Then the same leaf was put into the zinc sulphate solution and observed again. It was impossible, however, to test the same cells again. The whole observation was made within an hour and a half; and the specimens were left in the zinc sulphate solution not more than an hour.

The time required for a chloroplast to be carried the length of the cell was determined with a stop-watch that could be read to tenths of a second. Five such observatons were made for each cell and averaged. The length of the cell was then measured with a micrometer eyepiece. From twelve to twenty-five cells were tested for each concentration used. The lengths of the cells timed in one concentration were averaged; the average timings for the cells timed in one concentration were averaged; and the results were reduced so as to express the rate of movement for the concentration in terms of seconds per 100 microns. The results are also expressed in terms of per cent acceleration or retardation of the normal, or control, rate.

Most of the zinc sulphate test observations were made on different leaves from the controls, and all were made on different cells from the controls. On this account, a general average of all the normal observations was considered the best control to use for all concentrations. This base normal rate was an average of the timings of 137 cells.

For all the work with *Chara* the following method was used: A healthy-looking piece was taken from the tip of a plant, and observations were made on from one to four of its cells. The piece was then put into the test solution, and new observations were made on the same cells. Ten normal and ten test observations were made for each cell. All the observations on one piece were made within an hour and a half; and, for the most part, one piece was left in the test solution not longer than three quarters of an hour.

The time required for a particle in the cytoplasm to be carried the whole length of the micrometer scale was determined; under the

magnification used this was a distance of 595 microns. (For one concentration a distance of 420 microns was used.) From fifteen to eighteen cells were tested for each concentration. For the sake of comparison the averages were reduced to seconds per 100 microns, and as for *Elodea*, results are also given in terms of per cent acceleration of the normal.

Since the test and control observations were made on the same cells in every case, no base normal rate was calculated; the average of the normal timings of the particular cells tested for each concentration, was used as the normal for that concentration.

The work with *Chara* was more satisfactory than that with *Elodea* in several ways. Because of the larger size of the cells, it was possible to time the movement through a much greater distance, thus lessening the magnitnde of error. It was possible to obtain the normal rate for the same cells that were tested, thus limiting the factor of individual variation. Because of the greater ease of making observations and of finding suitable cells, it was possible, with the same expenditure of time, to make twice as many observations on each cell, thus again lessening the magnitude of error.

To prevent the crushing of *Chara* cells, the cover-glass was supported on two narrow strips of glass, cut from an ordinary slide. In general, in all this work, observations were made immediately upon placing the material under the microscope, and immediately after placing the material in test solutions. However, in case a cell showed a steady rise or fall in its rate, observations were continued until the rate became fairly uniform for the five or ten necessary consecutive observations. Uniformity was usually reached in a few minutes.

By reference to TABLE I and FIG. 1, it will be seen that very weak zinc sulphate solutions, 0.0002 *N* to 0.001 *N*, do accelerate the movement in *Elodea* cells. The concentration at which the greatest acceleration was observed was 0.0003 *N*, the acceleration being 14.85 per cent of the normal rate. Acceleration becomes less blow this concentration, and also falls off as the concentration rises. At 0.0015 *N* retardation is seen. There appears to be some irregularity in the retardation, but that was not the phenomenon of special interest in this study. By reference to TABLE II and

TABLE I

ELODEA

Fraction N $ZnSO_4$	No. of cells tested	Average distance in microns	Rate per 100 microns in seconds	% Acceleration of normal	% Retardation of normal
0.0000	137	105.30	16.83	0	0
0.0002	23	96.80	14.66	12.88	
0.0003	25	104.50	14.33	14.85	
0.0005	12	136.15	15.75	6.42	
0.0010	12	99.05	16.45	2.26	
0.0015	14	105.90	18.12		7.66
0.0020	19	120.50	17.26		2.56

FIG. 2 it will be seen that very weak zinc sulphate solutions, 0.0004 *N* to 0.0015 *N*, do accelerate the movement in *Chara* cells. The concentration at which the greatest acceleration was observed is 0.001 *N*, the acceleration being 20.58 per cent of the normal

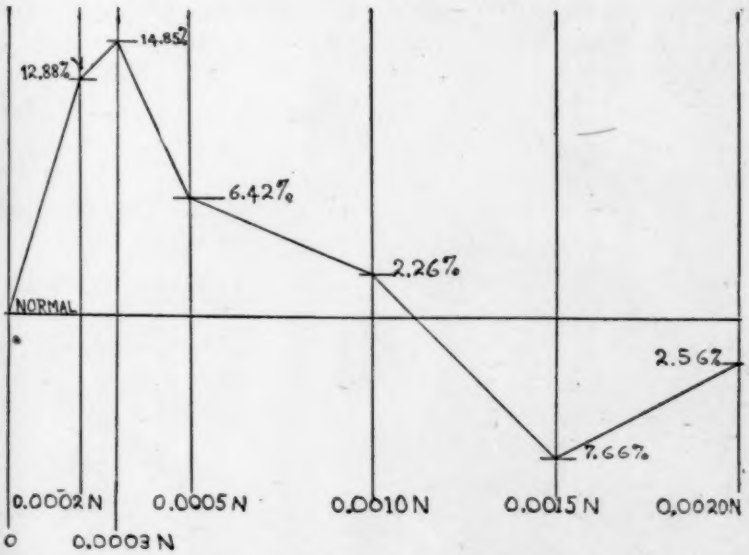

FIG. 1. Graph showing per cent acceleration (above "Normal" line) and retardation (below "Normal" line) of movement in *Elodea* cells by solutions of zinc sulphate.

rate. Acceleration becomes less below this strength until at 0.0003 *N* there is no effect at all. Acceleration also falls off as the strength increases, until at 0.002 *N* there is no effect. Higher concentrations were not investigated.

TABLE II

CHARA

	Fraction N $ZnSO_4$	No. of cells tested	Distance in microns	Rate per 100 microns in seconds	% Acceleration of normal
1	0.0000	18	595	2.485	0
	0.0003	18	595	2.485	0
2	0.0000	18	595	2.92	0
	0.0004	18	595	2.82	3.4
3	0.0000	18	595	2.69	0
	0.0005	18	595	2.41	10.41
4	0.0000	15	420	4.18	0
	0.0010	15	420	3.32	20.58
5	0.0000	18	595	2.71	0
	0.0015	18	595	2.45	9.6
6	0.0000	18	595	2.45	0
	0.0020	18	595	2.45	0

It appears, then, that *Elodea* cells are sensitive to weaker zinc sulphate than *Chara* cells, but that the maximum acceleration is less. It is also evident that the concentrations of zinc sulphate found by this study to cause the greatest acceleration of streaming

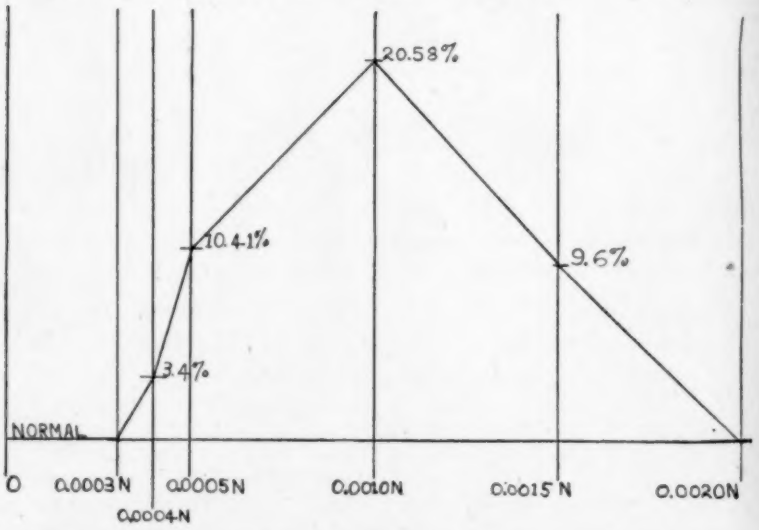

FIG. 2. Graph showing per cent acceleration of movement in *Chara* cells by solutions of zinc sulphate.

in *Elodea* and *Chara*, are in the neighborhood of those found to cause the greatest stimulation of the growth and metabolic activities in certain fungi by the work of Richards (**2, 3**) and Latham (**4**) already referred to.

The results of this study are offered as additional evidence that very dilute poisons act as stimulants to plant cells.

This work was done at the suggestion and under the direction of Dr. Herbert M. Richards, to whom the writer is greatly indebted for advice and encouragement.

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INDEX TO AMERICAN BOTANICAL LITERATURE

1914–1920

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Reviews, and papers that relate exclusively to forestry, agriculture, horticulture, manufactured products of vegetable origin, or laboratory methods are not included, and no attempt is made to index the literature of bacteriology. An occasional exception is made in favor of some paper appearing in an American periodical which is devoted wholly to botany. Reprints are not mentioned unless they differ from the original in some important particular. If users of the Index will call the attention of the editor to errors or omissions, their kindness will be appreciated.

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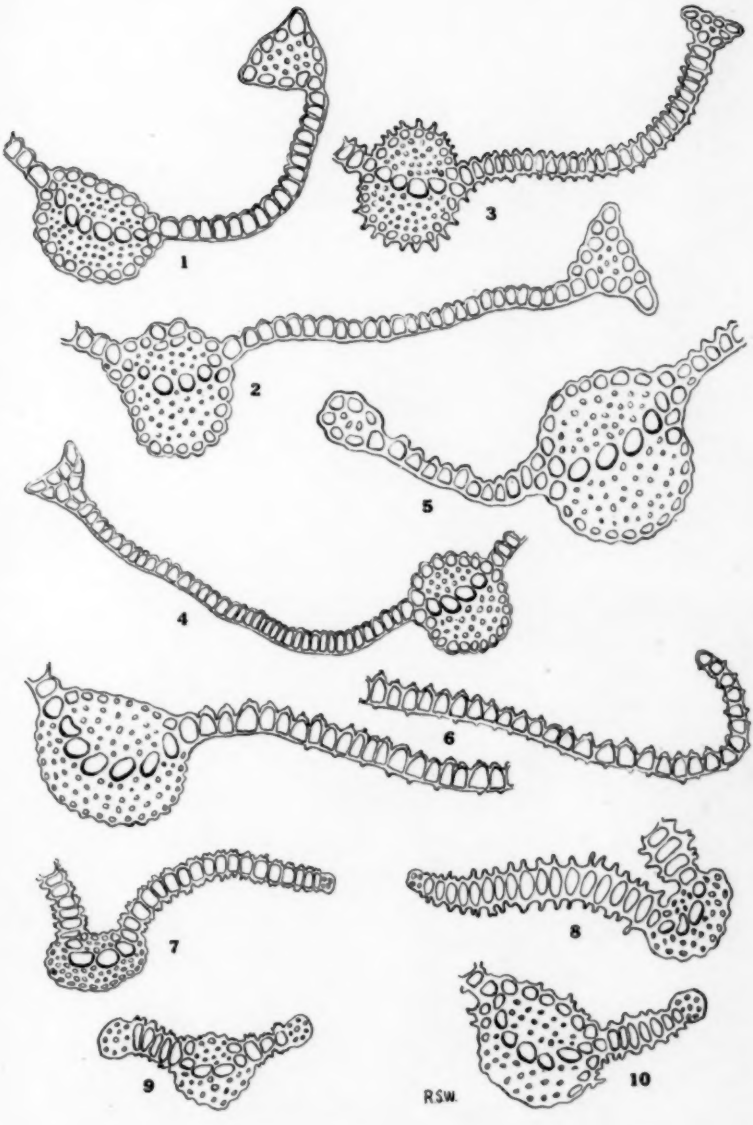

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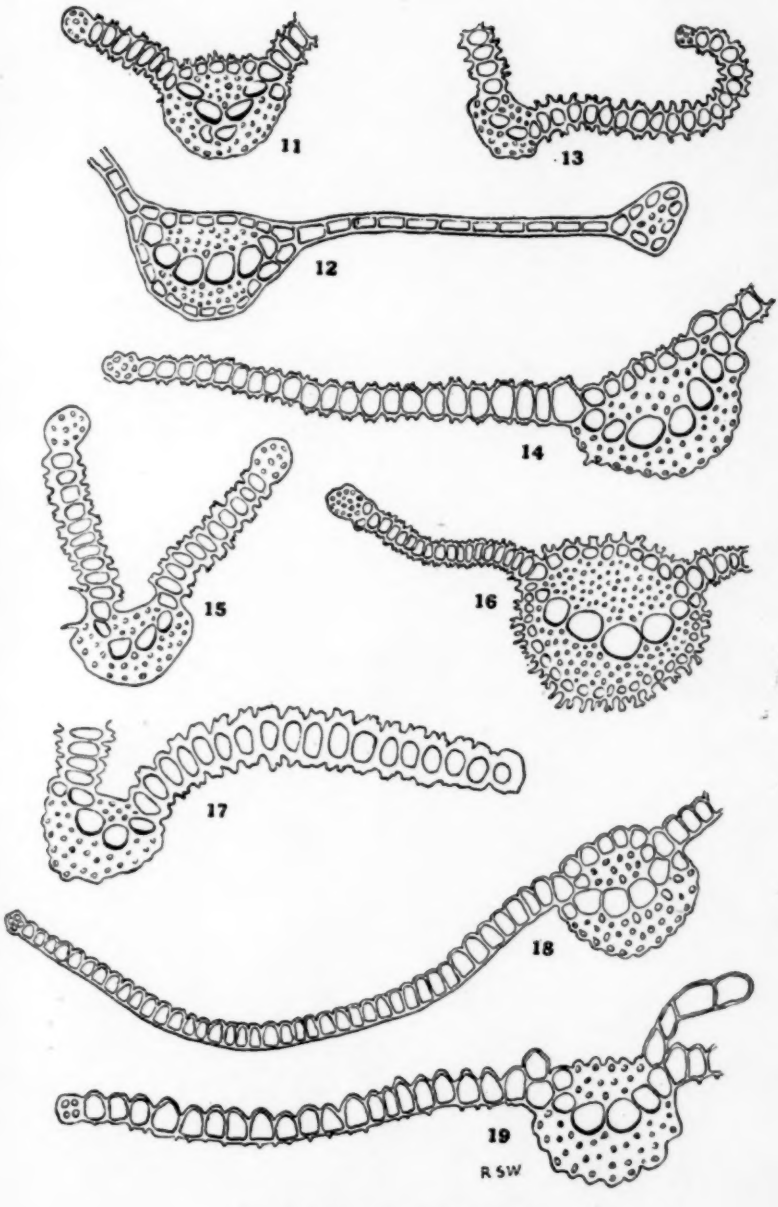

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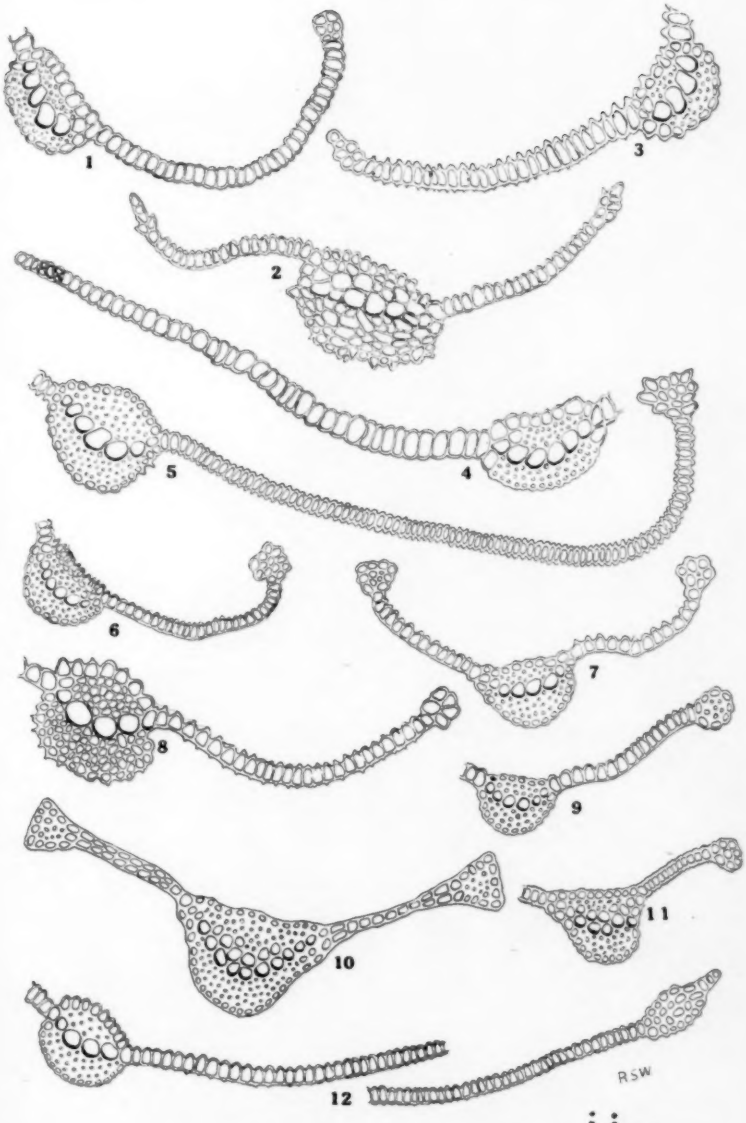

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